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VIBRA—An Interactive Computer Program for Steady-State Vibration Response Analysis of Linear Damped Structures

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Lynn M. Bowman

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VIBRA—An Interactive Computer Program for Steady-State Vibration Response Analysis of Linear Damped Structures

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National Aeronautics
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CONTENTS

INTRODUCTION

Steady-state vibration response analyses are commonly used in evaluating the dynamic behavior of structures subjected to cyclic external forces. An undocumented vibration response analysis based on modal superposition was developed about 10 years ago. The analysis calculates the acceleration response at any selected point on a structure for specified vibratory loading; the program provides tabular output of modal accelerations and acceleration response with optional paper plots.

In using the program, it became obvious that several improvements were desirable; thus, an effort was undertaken to expand the program's capability, to decrease "turnaround time," and to make the program easier to use. The mathematical equations used in the original program were retained, but a new program logic that would use less memory storage was developed. The new program operates interactively for rapid evaluation and plotting of structural response to vibratory loads. Options are also provided to control both the printed and the interactive graphic output.

The purpose of this report is to document the improved version of this computer program. The theoretical background, program description, and application are presented along with user instructions and a sample interactive computer session. The program can use results from any vibration analysis that has output in the form of generalized masses, eigenvalues, and eigenvectors. For instance, the program can be used as a postprocessor with finite-element codes such as NASTRAN® (ref. 1), or it can use measured modal data (as discussed in ref. 2). This computer program, named VIBRA (vibration response analysis), is available through COSMIC[1] as LAR-13291.

SYMBOLS

A	modal acceleration, g/lb
$[D(\omega)]$	damping matrix, lb-sec/in.
$d(\omega)$	generalized modal damping, lb-sec/in.
$\{F(\omega)\}$	applied force vector, lb
g	acceleration of gravity (G in computer-generated tables and plots), in/sec^2
g_n	structural damping coefficient (eq. (12))
i	imaginary operator
j	response coordinate
[K]	stiffness matrix, lb/in.
k	force coordinate

[1]COSMIC, 112 Barrow Hall, Univ. of Georgia, Athens, GA 30602.

M	generalized mass, lb-sec^2/in.
$[M]$	mass matrix, lb-sec^2/in.
N	number of modes
n	mode number index
$\{q(\omega)\}$	displacement response vector, in.
$\{\ddot{q}(\omega)\}$	acceleration response vector, g units
$[Y(\omega)]$	displacement mobility matrix, in/lb
$[\ddot{Y}(\omega)]$	acceleration mobility matrix, g/lb
$[Z(\omega)]$	displacement impedance matrix, lb/in.
$[\ddot{Z}(\omega)]$	acceleration impedance matrix, lb/g
ζ	critical damping ratio
ϕ	normalized mode
ψ	orthonormal mode, in$^{1/2}$/lb$^{1/2}$-sec
ω	forcing frequency
ω_n	natural frequency of nth mode, Hz

Superscripts:

I	imaginary component of complex variable
R	real component of complex variable
T	matrix transpose

Dots over a symbol define parameters in terms of acceleration.

METHOD OF ANALYSIS

The matrix equations of motion describing the dynamic behavior of linear, proportionally damped structures can be written in the frequency domain (ref. 2) by assuming simple harmonic motion:

$$(-\omega^2[M] + i\omega[D(\omega)] + [K])\{q(\omega)\} = \{F(\omega)\} \tag{1}$$

where [M] and [K] are real and symmetrical mass and stiffness matrices, and the symmetrical matrix $[D(\omega)]$ represents a general form of damping. The terms on the left side of equation (1) define the displacement impedance matrix $[Z(\omega)]$ such that

$$[Z(\omega)]\{q(\omega)\} = \{F(\omega)\} \tag{2}$$

Similarly, the acceleration impedance $[\ddot{Z}(\omega)]$ is defined as the matrix coefficients of accelerations, and equation (2) becomes

$$[\ddot{Z}(\omega)]\{\ddot{q}(\omega)\} = \{F(\omega)\} \tag{3}$$

The acclerations are obtained from equation (3) by

$$\{\ddot{q}(\omega)\} = [\ddot{Y}(\omega)]\{F(\omega)\} \tag{4}$$

where

$$[\ddot{Y}(\omega)] \equiv [\ddot{Z}(\omega)]^{-1}$$

The variables $\ddot{q}$ and $\ddot{Y}$ are not differentiated with respect to time but are intended to define responses in terms of acceleration. The variables in equation (4) are, in general, complex valued and frequency dependent. The matrix $[\ddot{Y}(\omega)]$ defined as acceleration mobility, is a transfer function which relates input excitations $\{F(\omega)\}$ to output accelerations $\{\ddot{q}(\omega)\}$. Acceleration responses are used in this formulation because test measurements are generally obtained from acceleration transducers. However, the acceleration mobility $\ddot{Y}$ can be related to the displacement mobility Y in the frequency domain by

$$\ddot{Y}(\omega) = -\omega^2\, Y(\omega) \tag{5}$$

Physically, the (jk)th element in the acceleration mobility matrix $\ddot{Y}_{jk}$ defines the response at j due to a force or moment at k. The acceleration mobility is composed of real and imaginary components, where $\ddot{Y}_{jk} = \ddot{Y}^R_{jk} + \ddot{Y}^I_{jk}$, and can be expressed in terms of modal parameters:

$$\ddot{Y}^R_{jk} = -\sum_{n=1}^{N} A_{jkn} \frac{(\omega/\omega_n)^2\left[1 - (\omega/\omega_n)^2\right]}{\left[1 - (\omega/\omega_n)^2\right]^2 + d_n(\omega)^2} \tag{6}$$

$$\ddot{Y}^{I}_{jk} = \sum_{n=1}^{N} A_{jkn} \frac{(\omega/\omega_n)^2 d_n(\omega)}{\left[1 - (\omega/\omega_n)^2\right]^2 + d_n(\omega)^2} \tag{7}$$

where ω_n is the natural frequency of the nth normal mode and A_{jkn} is the (jk)th modal acceleration of the nth normal mode defined by

$$A_{jkn} = \frac{\phi_{jn}\phi_{kn}}{M_n} \tag{8}$$

The orthogonal modal vector $\{\phi\}_n$ and mass matrix $[M]$ are combined to calculate the generalized mass M_n in equation (8) by

$$\{\phi\}_n^T [M]\{\phi\}_n = M_n \tag{9}$$

If the modal vector is scaled such that

$$\{\phi\}_n^T [M]\{\phi\}_n = 1.0 \tag{10}$$

then the modal vector is the orthonormal modal vector $\{\phi\}_n$, and

$$A_{jkn} = \phi_{jn}\phi_{kn} \tag{11}$$

Reference 2 includes a complete derivation of the modal superposition equations described in equations (6) and (7). The modal damping $d_n(\omega)$ can be defined as structural or viscous. For structural damping

$$d_n(\omega) \equiv g_n \tag{12}$$

and for viscous damping

$$d_n(\omega) \equiv 2\zeta \frac{\omega}{\omega_n} \tag{13}$$

where ζ is the critical damping ratio.

In principle, the number of modes N is infinite; in practice, only a finite number of modes are necessary over a specified frequency range. For unconstrained structures, N includes both rigid-body and elastic modes. These modal parameters can be derived from either test or analysis, as appropriate.

PROGRAM ORGANIZATION

Program Description

The VIBRA program (vibration response analysis) uses equations (6) and (7) to develop the acceleration mobilities and equations (8) and (11) to form the modal accelerations. The structural responses are determined for known force excitations using equation (4). Therefore the structure to be analyzed must be described by a consistent set of eigenvectors, eigenvalues, and generalized mass data. These modal data may be obtained from any natural vibration analysis or from ground vibration measurements of the structure. Only the modal data at the selected response and applied vibratory load points are required to calculate the forced response of the structure.

Program Flow

A flow chart of the VIBRA program is shown in figure 1 with prepared input data read from file 7. As shown in the figure, the program reads in a title card, a control card, natural frequencies ω_n, damping coefficients ζ, generalized mass M_n, and one or more force vector sets $\{F(\omega)\}$ followed by the modal coordinates $\{\phi_{n=1,N}\}_k$ at the respective load point k. The complex valued force vector $\{F(\omega)\}$ defines the magnitude and direction, while the modal coordinates $\{\phi_{n=1,N}\}$ at the applied load point k define the location of the force vector. Next, one set of modal coordinates $\{\phi_{n=1,N}\}_j$ at the response point j is read from input file 7. The program calculates one response point at a time. The modal accelerations, acceleration mobilities, and acceleration responses are calculated for this response point. Then, print options are available to output these results either on the terminal screen or output file 8, or both. Next, VIBRA produces a plot which displays the acceleration response $\ddot{q}$ versus forcing frequency ω in four component plots consisting of (1) real acceleration versus ω, (2) imaginary acceleration versus ω, (3) amplitude versus ω, and (4) phase angle versus ω. After reviewing the plot, the user has the option to plot any of the component plots separately on the screen or continue execution. At this point the user specifies a value for the NAMELIST VPLOT parameter NPLOT to indicate the next desired operation.

Figure 1 shows the program logic determined by the value specified for NPLOT. A positive value of 1, 2, 3, 4, or 5 for NPLOT causes the program to display the plot and then continue with the next desired program operation. For a negative value, -2, -3, -4, or -5, no plot is created but the program continues with the next desired operation. A value of NPLOT = 1 instructs the program to read another NAMELIST VPLOT. A value of NPLOT = +2 or -2 causes the program to apply the next force set, if there is more than one input, to the present response case. A value of NPLOT = +3 or -3 instructs the next response group to be read from input file 7. If the previous response case was calculated using other than the first force vector set, the first force vector set will be used again when the next response case is read. A value of NPLOT = +4 or -4 causes the program to read a title card for a new problem. To exit the program, a value of NPLOT = +5 or -5 must be used.

Appendix A contains detailed information on the data and format requirements for the prepared input file 7. The type of interactive input required by VIBRA and a description of the namelist parameters are provided also. To demonstrate the flow and graphics capability of the program, an example problem is solved in an interactive session provided in appendix B. Also included in appendix B is a brief description of the example problem's modal data and how the data are arranged in file 7.

Appendix C contains information on computer memory requirements, auxiliary storage files, and graphics subroutines.

APPLICATIONS

Applications are presented for a constrained viscously damped system (case 1) and an unconstrained structurally damped helicopter tail boom (case 2). These applications were selected to demonstrate the versatility of the VIBRA program.

Case 1 - Constrained Viscously Damped System

Case 1 demonstrates two methods of applying forces to a system. The modal data, given in table I, are for the constrained system with no damping. However, the damping terms may be included when calculating response because of the modal superposition principle.

Case 1A, as shown in figure 2(a), is the constrained system with a unit force applied at node 1 with response to be calculated at node 1 (the driving point) and at node 5 (a transfer point), assuming 2.5 percent viscous damping for all modes. Table II shows the VIBRA input data file 7. The problem title and the control parameters given in line 2 of table II are described in table III. The force has a frequency ranging from 0 to 50 Hz with an increment of 1 Hz. Acceleration responses for nodes 1 and 5 are given in tables IV and V, while the corresponding plots are shown in figures 3 and 4.

Case 1B, as shown in figure 2(b), has multiple forces applied at nodes 1, 2, and 3, assuming variable viscous damping. Tables VI and VII describe the force vector sets and damping data, respectively. The force vectors are composed of real and imaginary parts with different magnitudes and directions. Both vector sets have a 20-Hz forcing frequency. Because the responses are calculated for only one frequency, no plots can be generated. The input data file for case 1B is given in table VIII, with the problem title and control parameters description shown in table IX. Responses are calculated at all locations for both vector sets. Tables X and XI show the modal acceleration matrix, acceleration mobility, and acceleration response for nodes 1 and 2. Table XII gives the acceleration response for nodes 3, 4, and 5.

Case 2 - Unconstrained Structurally Damped Helicopter Tail Boom

Undamped modal data for the helicopter tail boom shown in figure 5 were obtained from a finite-element analysis and reformatted for input to VIBRA. The assumed damping terms are included in the input file. As figure 5 shows, a unit force is applied at the end of the tail boom (node location 193) and the response is calculated near the midsection (node 109). Table XIII shows the input data file 7. Only modal data at the load and response node locations are required. Data are input for a total of 12 orthonormal modes of which the first 6 are rigid-body modes. The forcing frequency ranges from 75 to 300 Hz with a frequency increment of 1 Hz. Since the modes are orthonormal, the generalized mass has a value of 1.0 for all modes. The assumed structural damping coefficients are input on line 10 of table XIII, with values ranging from 1.5 to 1.6 percent. The problem title and control parameter description are given in table XIV.

A plot of node 109 response is shown in figure 6; the real acceleration component is examined further in figures 7 and 8 by using the zoom feature. The zoom feature, described in appendix B, allows the user to define a portion of a plot to be expanded. Figure 8 shows a flattened peak around 212 Hz. This effect is due to not calculating response exactly at the natural frequency. In view of these results, care must be taken when determining the frequency increment. The imaginary component of the acceleration response is shown in figure 9, and the amplitude response is shown in figure 10.

CONCLUDING REMARKS

An interactive computer program (VIBRA) for calculating steady-state frequency response of linear, proportionally damped structures has been described. The program uses a modal superposition approach to calculate the structural response. The response is calculated as a function of frequency and in terms of acceleration. The program has interactive graphics capabilities to display the acceleration response versus forcing frequency. The interactive capability enables rapid evaluation of the structural response. Sample problems consisting of several simple systems and a complex system demonstrate program versatility.

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May 29, 1984

APPENDIX A

INPUT DATA DESCRIPTION

VIBRA Input File 7 Data and Format Requirements

The input consists of prepared data on file 7 and interactive input from a keyboard. VIBRA reads the input data file 7 using list-directed read statements. Therefore, all numerical data can be entered on a card image in any column. The only requirement is that the data must be separated by blanks or commas. A blank space cannot be used for a zero. As shown in tables II, VIII, and XIII, a typical input file consists of

1. A card containing the problem title
2. A control card specifying parameters
3. Natural frequency group
4. Generalized mass group
5. Damping group
6. Force vector group(s)
7. Force coordinate group(s)
8. Response coordinate group(s)

A data group is defined by a single title card with information identifying the group, followed by one or more cards containing the data values. The data values are entered in free-field format. Except for the force vector group, where only a maximum of six groups may be input, there is no limit on the number of force and response coordinate groups that can be input for one problem. Also, there is no limit on the number of problems that can be on the same input file. The description and format for the data file are given in the following eight sections.

Title card.- A single card contains the problem title.

FORTRAN variable name	Description
TITLE	Heading information for printout

Control card.- Each of the 10 parameters listed on the control card must be specified and entered in the following order:

FORTRAN variable name	Description
NZ	Number of rigid body modes
NM	Total number of modes (rigid + elastic)
MNORM	Type of mode: 1 orthonormal modes (one term input) 0 normal modes (NM terms input)

FORTRAN variable names	Description
MDAMP	Type of modal damping: 1 viscous damping 0 structural damping
NZETA	Variable damping control: 1 damping is the same for all modes (one term input) 0 damping varies for each mode (NM terms are input)
NFS	Number of force vector groups (maximum of 6)
NF	Number of forces applied to structure (if NF > 1, then only one frequency point will be calculated using the WSTRT value)
WSTRT	Starting frequency point, Hz
WSTOP	Ending frequency point, Hz
DELW	Frequency step

Natural frequency group.- The natural frequency group is

Card	FORTRAN variable name	Description
1	WLABEL	Group title card
2+	WN, Hz	Natural frequency for nth mode

Note: There should be NM terms input.

Generalized mass group.- The generalized mass group is

Card	FORTRAN variable name	Description
1	MLABEL	Group title card
2+	M, lb-sec^2/in.	Generalized mass for nth mode

Note: If MNORM = 1, one mass term is input (orthonormal modes); If MNORM = 0, NM terms are input.

Damping group.- The damping group is

Card	FORTRAN variable name	Description
1	GLABEL	Group title card
2+	G	Modal damping coefficient (for viscous damping, enter ζ; for structural damping enter 2ζ)

Note: If NZETA = 1, one damping term is input (damping same for all modes); if NZETA = 0, NM terms are input.

Force vector group.- The force vector group is

Card	FORTRAN variable name	Description
1	FLABEL	Group title card
2+	F, lb	Complex force vector, (F^R, F^I)

Note: There should be NFS force vector groups and NF forces for each vector group. The order in which each force is entered also determines the order that the force coordinate groups are input. The vector group forms the magnitudes and directions of the forces applied to the structure. A maximum of six force vector groups may be input.

Force coordinate group.- The force coordinate group is

Card	FORTRAN variable name	Description
1	PLABEL	Group title card
2+	PHI	Force modal coordinate for nth mode

Note: There should be NF force coordinate groups and NM terms for each group. The force coordinate groups must follow the same input order as the force vectors. The force coordinate defines the location where the vectors are applied. When more than one force coordinate group is entered, only one frequency point is calculated for the response.

Response coordinate group.- The response coordinate group is

Card	FORTRAN variable name	Description
1	RLABEL	Group title card
2+	PHIBAR	Response modal coordinate for nth mode

Note: There should be NM terms input for each group. There can be as many groups as desired, the only limit being the total number of degrees of freedom of the structure. To calculate the response at the driving point, input the particular force coordinate group as a response group also.

VIBRA Interactive Input

Input from the interactive terminal keyboard is prompted by the program. Keyboard input includes pressing the carriage return key to advance to the next program section, answering questions with the character Y or N for yes or no, specifying print options for the output of results, and entering NAMELIST VPLOT data. In specifying print options, the program provides a screen menu with input instructions. NAMELIST VPLOT is used to specify program flow and plot options. In the first part of this section, the NAMELIST parameters and their default values are described; in the second part, NAMELIST rules are given.

Contents of NAMELIST VPLOT.- Descriptions of the NAMELIST parameters and their default values are as follows:

QREAL
  1 Plot real acceleration versus forcing frequency
  0 No plot (default)

QIMAG
  1 Plot imaginary acceleration versus forcing frequency
  0 No plot (default)

AMPL
  1 Plot acceleration amplitude versus forcing frequency
  0 No plot (default)

PHASE
  1 Plot phase angle versus forcing frequency
  0 No plot (default)

APPENDIX A

USCALE
  1 Input minimum and maximum values for X- and Y-axes
  0 Automatic program scaling of plot axes (default)

If USCALE = 1, the following parameters must be selected and specified to change the default values:

XMIN is minimum value for X-axis (forcing frequency value); default, 0.0

XMAX is maximum value for X-axis (forcing frequency value); default, 10.0

YMIN is minimum value for Y-axis (response value); default, 0.0

YMAX is maximum value for Y-axis (response value); default, 10.0

The following parameters may be specified:

JLINE Selects number of data points to be plotted:
- n plot every nth point
- 1 (default)

XDIV Number of minor tick mark divisions for X-axis (default, 10.0)

YDIV Number of minor tick mark divisions for Y-axis (default, 10.0)

LTYPE Type of line for plotting:
- -1 no line
- 0 solid (default)
- 1 long dash
- 2 dash
- 3 dot dash
- 4 dot

ISYM Symbol type:
- 0 no symbol (default)
- 1 circle
- 3 triangle
- 4 square
- 5 star
- 6 diamond
- 7 plus sign

ISIZE Multiplicative factor for symbol size:
- 1 small symbols (default)
- 2 medium symbols
- 3 large symbols

APPENDIX A

NPLOT Control loop parameter:

1 plot response then read another NAMELIST VPLOT
2 plot response then apply next force vector set
3 plot response then read another response group
4 plot response then read another problem
5 plot response then exit the program (default)

-2 no plot but apply next force vector set
-3 no plot but read another response group
-4 no plot but read another problem
-5 no plot and exit the program

Note: Figure 1 shows how the NPLOT parameter controls looping within the program. Also, all previous responses must have been calculated to position the input file for reading another problem title.

<u>NAMELIST rules</u>.- The following NAMELIST rules apply to most FORTRAN systems:

1. A NAMELIST begins in column 2 with a dollar sign, e.g.,

```
12345678910 . . . . . . . . . . . . . . . . . . 80
 $VPLOT
```

2. NAMELIST parameters are separated by commas.

3. NAMELISTS end with a blank and then a dollar sign, no final comma, e.g.,

```
$VPLOT QREAL=1,NPLOT=+2 $
```

4. If more than one line is used to enter a namelist, then that line must end with a comma, e.g.,

```
$VPLOT QREAL=1,NPLOT=2,USCALE=1,
XMIN=0.0,XMAX=45.0,YMIN=0.0,YMAX=5.0 $
```

Blank Common Length

VIBRA uses the control card parameters to determine the location of program variables within the blank common array ZZZ, which has a set length of 5000 decimal memory locations. The number of required memory locations for a problem can be determined from

$$BCL = 5*(1+NM) + NF*(NM+2*NFS+4) + (5*IFN) + 6$$

where

$$IFN = (WSTOP - WSTRT)/DELW + 1$$

which is the number of forcing frequency step points.

APPENDIX B

SAMPLE INTERACTIVE SESSION

In the sample interactive session, responses are calculated at mass 1 and mass 2 of the unconstrained spring mass system shown in figure B1 for a unit force applied at mass 3. The force has a frequency ranging from 0 Hz to 20 Hz in 0.5-Hz increments. Modal data for the system, obtained from a simple vibration analysis program, are shown in table BI. The system has one rigid-body and two elastic normal modes.

The input data file 7 for this program is given in table BII. The natural frequencies and generalized masses from table BI are input in modal order as shown in table BII, lines 4 and 6, respectively. The complex force, table BII, line 10, has a real component term only. In order to apply the force at mass 3, the modal amplitudes at mass 3 are entered as the force coordinates, as shown in line 12 of table BII. Similarly, to evaluate the responses at mass 1 and mass 2, modal amplitudes at those points are entered in line 14 and line 16, respectively. If the response at mass 3 was desired, the corresponding modal amplitudes would have to be reentered as response coordinates also.

After the input file 7 is prepared, the user is ready to execute VIBRA on an interactive graphics terminal. This section describes a typical interactive session using the input file 7 for the spring mass system, table BII. For each new problem the first screen page contains a title and descriptive table of control parameters, as shown in table BIII. VIBRA pauses after each screen page to allow for viewing and obtaining a hard copy. When the terminal bell rings, the program temporarily stops execution until the return key is pressed. Pressing the return key erases the screen and causes VIBRA to continue to the next program operation.

After VIBRA calculates a response case, a print menu is displayed. As shown in table BIV, option 2 is selected for the first three questions. This causes the modal accelerations, acceleration mobilities, and response tables to be output to auxiliary file 8. The next two questions control print output. In this example, 50 lines of output per page for file 8, using a print step of 1, were selected. A print step of 1 causes every frequency point to be printed. Upon completion of the print menu, VIBRA pauses until the carriage return is pressed.

Next, a preview plot of the response components is given automatically, as shown in figure B2. VIBRA pauses upon completion of the plot until the carriage return key is pressed, which causes VIBRA to prompt for NAMELIST VPLOT input. As table BV shows, the real acceleration component plot is selected by setting the QREAL parameter equal to 1. The NPLOT parameter is defined to be a positive 3. This means the selected component will be plotted and then another response will be calculated using the same force vector set as the previous group. After the grid question in table BV is answered, VIBRA immediately erases the screen, and the response is plotted in figure B3 with a question at the bottom of the screen to zoom in on the graph. The zoom option enables the user to examine any portion of a response plot on an expanded scale. The user defines the scale by entering two position coordinates, upper left and lower right. Figure B3 shows that the zoom option is selected. Cursor cross hairs appear on the screen and are moved by using the terminal thumbwheels. The two position coordinates are entered one at a time. The coordinates are input by positioning the cross hairs at the desired point, pressing any key (followed by a carriage return), and waiting for the terminal bell to ring. The cross hairs disappear momentarily until the coordinate is received; then the terminal bell rings. After

the coordinates are entered, VIBRA draws a box around the portion of the plot to be expanded, and then pauses. After the carriage return key is pressed, the boxed portion shown in figure B4 is then replotted as shown in figure B5.

Because NPLOT = 3 was specified, the next response will be calculated at mass 2. As shown in table BVI, the modal accelerations, acceleration mobility, and acceleration response for mass 2 are output to file 8. The program loop continues, as shown by figure B6, table BVII, and figure B7, until the NPLOT parameter is equal to a positive or a negative 5; this causes the program to terminate. Table BVIII shows the contents of file 8, which was saved after finishing the interactive session.

TABLE BI.- MODAL DATA FOR UNCONSTRAINED SPRING MASS

Mode	Frequency, Hz	Generalized mass	Mode shape		
1	0.0	10.0	1.0	1.0	1.0
2	7.749	1.179	1.0	.051649	-.157615
3	15.442	2.514	-.3615	1.0	-.234066

TABLE BII.- INPUT DATA FILE 7 FOR SPRING MASS SYSTEM

```
SPRING MASS SYSTEM
1 3 0 1 1 1 1  0.0   20.0   0.5
NATURAL FREQUENCY
0.0  7.749  15.442
GENERALIZED MASS
10.0  1.179  2.514
DAMPING
0.0
FORCE AT MASS 3
(1.0,0.0)
MASS 3 - FORCE COORDINATE
1.0  -.157615  -.234066
MASS 1 - RESPONSE COORDINATE
1.0  1.0  -.3615
MASS 2 - RESPONSE COORDINATE
1.0  0.051649  1.0
```

TABLE BIII.- CONTROL PARAMETER DESCRIPTION FOR SPRING MASS SYSTEM

```
                SPRING MASS SYSTEM


CONTROL PARAMETERS SET

NZ     =  1 *RIGID BODY MODES*
NM     =  3 *MODES TOTAL*
MNORM  =  0 *NORMAL MODES*
MDAMP  =  1 *VISCOUS DAMPING*
NZETA  =  1 *DAMPING IS CONSTANT*
NFS    =  1 *FORCE VECTOR SETS*
NF     =  1 *FORCE COORDINATES*
WSTRT  =    .0 *STARTING FREQUENCY (HZ) *
WSTOP  =  20.0 *STOPPING FREQUENCY (HZ) *
DELW   =    .500 *FREQUENCY STEP*
          BLANK COMMON STORAGE ZZZ REQUIRES    279 LOCATIONS

          NOW COMPUTING FORCED RESPONSE
```

TABLE BIV.- PRINT MENU FOR MASS 1 RESPONSE

```
 SPRING MASS SYSTEM
APPLIED FORCE VECTOR:  FORCE AT MASS 3
RESPONSE LOCATION:  MASS 1 - RESPONSE COORDINATE

  FOR THE NEXT 3 QUESTIONS ENTER 1 OF THE FOLLOWING PRINT OPTIONS:
                             OPTIONS
  OUTPUT TO SCREEN............1
  OUTPUT TO TAPE8.............2
  OUTPUT TO SCREEN & TAPE8.....3
  NO OUTPUT AT ALL.............4
   MODAL ACCELERATIONS?  (DEFAULT 3)
? 2
  ACCELERATION MOBILITIES?   (DEFAULT 3)
? 2
  RESPONSE TABLE?   (DEFAULT 3)
? 2
  ENTER NUMBER OF LINES PER PAGE FOR TAPE8   (DEFAULT 40)
? 50
  ENTER PRINT STEP   (DEFAULT 1)
? 1
```

TABLE BV.- NAMELIST VPLOT INPUT FROM TERMINAL KEYBOARD FOR MASS 1 RESPONSE PLOT

```
ENTER $VPLOT NAMELIST:

?  $VPLOT QREAL=1,NPLOT=3 $


-$VPLOT
0QREAL    = 1,
0QIMAG    = 0,
0AMPL     = 0,
0PHASE    = 0,
0NPLOT    = 3,
0USCALE   = 0,
0XMIN     = 0.0,
0XMAX     = .1E+02,
0YMIN     = 0.0,
0YMAX     = .1E+02,
0JLINE    = 1,
0ISYM     = 0,
0ISIZE    = 1,
0LTYPE    = 0,
0XDIV     = .1E+02,
0YDIV     = .1E+02,
0$END

NEED GRIDS?   (Y/N)
? N
```

APPENDIX B

TABLE BVI.- PRINT MENU FOR MASS 2 RESPONSE

```
     SPRING MASS SYSTEM
    APPLIED FORCE VECTOR:  FORCE AT MASS 3
    RESPONSE LOCATION:  MASS 2 - RESPONSE COORDINATE

      FOR THE NEXT 3 QUESTIONS ENTER 1 OF THE FOLLOWING PRINT OPTIONS:
                                OPTIONS
      OUTPUT TO SCREEN.............1
      OUTPUT TO TAPE8..............2
      OUTPUT TO SCREEN & TAPE8.....3
      NO OUTPUT AT ALL.............4
       MODAL ACCELERATIONS?  (DEFAULT 3)
? 2
      ACCELERATION MOBILITIES?   (DEFAULT 3)
? 2
      RESPONSE TABLE?   (DEFAULT 3)
? 2
      ENTER NUMBER OF LINES PER PAGE FOR TAPE8   (DEFAULT 40)
? 50
      ENTER PRINT STEP   (DEFAULT 1)
? 1
```

TABLE BVII.- NAMELIST VPLOT INPUT MASS 2 RESPONSE PLOT

```
 ENTER $VPLOT NAMELIST:

?  $VPLOT QREAL=1,ISYM=1,NPLOT=5 $



-$VPLOT
0QREAL   = 1,
0QIMAG   = 0,
0AMPL    = 0,
0PHASE   = 0,
0NPLOT   = 5,
0USCALE  = 0,
0XMIN    = 0.0,
0XMAX    = .1E+02,
0YMIN    = 0.0,
0YMAX    = .1E+02,
0JLINE   = 1,
0ISYM    = 1,
0ISIZE   = 1,
0LTYPE   = 0,
0XDIV    = .1E+02,
0YDIV    = .1E+02,
0$END

NEED GRIDS?   (Y/N)
? N
```

TABLE BVIII.- FILE 8 SAMPLE OUTPUT OF SPRING MASS SYSTEM RESPONSES

```
********** V I B R A **********
INPUT DATA CARD IMAGE FILE
CARD
  1      SPRING MASS SYSTEM
  2      1 3 0 1 1 1 1  0.0   20.0  0.5
  3      NATURAL FREQUENCY
  4      0.0  7.749  15.442
  5      GENERALIZED MASS
  6      10.0  1.179  2.514
  7      DAMPING
  8      0.0
  9      FORCE AT MASS 3
 10      (1.0,0.0)
 11      MASS 3 - FORCE COORDINATE
 12      1.0  -.157615  -.234066
 13      MASS 1 - RESPONSE COORDINATE
 14      1.0  1.0  -.3615
 15      MASS 2 - RESPONSE COORDINATE
 16      1.0  0.051649  1.0

  SPRING MASS SYSTEM

  APPLIED FORCE VECTOR: FORCE AT MASS 3
  RESPONSE LOCATION: MASS 1 - RESPONSE COORDINATE

  MODAL ACCELERATION MATRIX A(NF,NM)
 .1000E+00 -.1337E+00  .3366E-01

  SPRING MASS SYSTEM

 APPLIED FORCE VECTOR:  FORCE AT MASS 3
 RESPONSE LOCATION:  MASS 1 - RESPONSE COORDINATE

 ACCELERATION MOBILITY Y(NR,NF)
N      FREQ     YR         YI
 1     0.000  .1000E+00 0.
 2      .500  .1005E+00 0.
 3     1.000  .1021E+00 0.
 4     1.500  .1049E+00 0.
 5     2.000  .1090E+00 0.
 6     2.500  .1146E+00 0.
 7     3.000  .1222E+00 0.
 8     3.500  .1324E+00 0.
 9     4.000  .1461E+00 0.
10     4.500  .1649E+00 0.
11     5.000  .1914E+00 0.
12     5.500  .2308E+00 0.
13     6.000  .2942E+00 0.
14     6.500  .4101E+00 0.
15     7.000  .6843E+00 0.
16     7.500  .2070E+01 0.
17     8.000 -.2077E+01 0.
18     8.500 -.7061E+00 0.
19     9.000 -.4341E+00 0.
20     9.500 -.3200E+00 0.
21    10.000 -.2589E+00 0.
22    10.500 -.2225E+00 0.
23    11.000 -.2001E+00 0.
24    11.500 -.1868E+00 0.
25    12.000 -.1806E+00 0.
26    12.500 -.1811E+00 0.
27    13.000 -.1893E+00 0.
28    13.500 -.2085E+00 0.
29    14.000 -.2481E+00 0.
30    14.500 -.3380E+00 0.
31    15.000 -.6452E+00 0.
32    15.500  .4428E+01 0.
33    16.000  .4165E+00 0.
34    16.500  .1996E+00 0.
35    17.000  .1237E+00 0.
36    17.500  .8575E-01 0.
37    18.000  .6338E-01 0.
38    18.500  .4885E-01 0.
39    19.000  .3879E-01 0.
40    19.500  .3150E-01 0.
41    20.000  .2604E-01 0.
```

TABLE BVIII.- Continued

SPRING MASS SYSTEM

APPLIED FORCE VECTOR: FORCE AT MASS 3
RESPONSE LOCATION: MASS 1 - RESPONSE COORDINATE

FORCING FREQUENCY (HERTZ)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
.0000	.1000E+00	.0000E+00	.1000E+00	.0000E+00	.2588E-03	.0000E+00	.2588E-03
.5000	.1005E+00	.0000E+00	.1005E+00	.0000E+00	.2602E-03	.0000E+00	.2602E-03
1.0000	.1021E+00	.0000E+00	.1021E+00	.0000E+00	.2643E-03	.0000E+00	.2643E-03
1.5000	.1049E+00	.0000E+00	.1049E+00	.0000E+00	.2714E-03	.0000E+00	.2714E-03
2.0000	.1090E+00	.0000E+00	.1090E+00	.0000E+00	.2820E-03	.0000E+00	.2820E-03
2.5000	.1146E+00	.0000E+00	.1146E+00	.0000E+00	.2966E-03	.0000E+00	.2966E-03
3.0000	.1222E+00	.0000E+00	.1222E+00	.0000E+00	.3164E-03	.0000E+00	.3164E-03
3.5000	.1324E+00	.0000E+00	.1324E+00	.0000E+00	.3428E-03	.0000E+00	.3428E-03
4.0000	.1461E+00	.0000E+00	.1461E+00	.0000E+00	.3782E-03	.0000E+00	.3782E-03
4.5000	.1649E+00	.0000E+00	.1649E+00	.0000E+00	.4268E-03	.0000E+00	.4268E-03
5.0000	.1914E+00	.0000E+00	.1914E+00	.0000E+00	.4954E-03	.0000E+00	.4954E-03
5.5000	.2308E+00	.0000E+00	.2308E+00	.0000E+00	.5974E-03	.0000E+00	.5974E-03
6.0000	.2942E+00	.0000E+00	.2942E+00	.0000E+00	.7613E-03	.0000E+00	.7613E-03
6.5000	.4101E+00	.0000E+00	.4101E+00	.0000E+00	.1061E-02	.0000E+00	.1061E-02
7.0000	.6843E+00	.0000E+00	.6843E+00	.0000E+00	.1771E-02	.0000E+00	.1771E-02
7.5000	.2070E+01	.0000E+00	.2070E+01	.0000E+00	.5357E-02	.0000E+00	.5357E-02
8.0000	-.2077E+01	.0000E+00	.2077E+01	.1800E+03	-.5375E-02	.0000E+00	.5375E-02
8.5000	-.7061E+00	.0000E+00	.7061E+00	.1800E+03	-.1827E-02	.0000E+00	.1827E-02
9.0000	-.4341E+00	.0000E+00	.4341E+00	.1800E+03	-.1123E-02	.0000E+00	.1123E-02
9.5000	-.3200E+00	.0000E+00	.3200E+00	.1800E+03	-.8281E-03	.0000E+00	.8281E-03
10.0000	-.2589E+00	.0000E+00	.2589E+00	.1800E+03	-.6701E-03	.0000E+00	.6701E-03
10.5000	-.2225E+00	.0000E+00	.2225E+00	.1800E+03	-.5759E-03	.0000E+00	.5759E-03
11.0000	-.2001E+00	.0000E+00	.2001E+00	.1800E+03	-.5177E-03	.0000E+00	.5177E-03
11.5000	-.1868E+00	.0000E+00	.1868E+00	.1800E+03	-.4834E-03	.0000E+00	.4834E-03
12.0000	-.1806E+00	.0000E+00	.1806E+00	.1800E+03	-.4674E-03	.0000E+00	.4674E-03
12.5000	-.1811E+00	.0000E+00	.1811E+00	.1800E+03	-.4687E-03	.0000E+00	.4687E-03
13.0000	-.1893E+00	.0000E+00	.1893E+00	.1800E+03	-.4898E-03	.0000E+00	.4898E-03
13.5000	-.2085E+00	.0000E+00	.2085E+00	.1800E+03	-.5396E-03	.0000E+00	.5396E-03
14.0000	-.2481E+00	.0000E+00	.2481E+00	.1800E+03	-.6421E-03	.0000E+00	.6421E-03
14.5000	-.3380E+00	.0000E+00	.3380E+00	.1800E+03	-.8748E-03	.0000E+00	.8748E-03
15.0000	-.6452E+00	.0000E+00	.6452E+00	.1800E+03	-.1670E-02	.0000E+00	.1670E-02
15.5000	.4428E+01	.0000E+00	.4428E+01	.0000E+00	.1146E-01	.0000E+00	.1146E-01
16.0000	.4165E+00	.0000E+00	.4165E+00	.0000E+00	.1078E-02	.0000E+00	.1078E-02
16.5000	.1996E+00	.0000E+00	.1996E+00	.0000E+00	.5166E-03	.0000E+00	.5166E-03
17.0000	.1237E+00	.0000E+00	.1237E+00	.0000E+00	.3201E-03	.0000E+00	.3201E-03
17.5000	.8575E-01	.0000E+00	.8575E-01	.0000E+00	.2219E-03	.0000E+00	.2219E-03
18.0000	.6338E-01	.0000E+00	.6338E-01	.0000E+00	.1640E-03	.0000E+00	.1640E-03
18.5000	.4885E-01	.0000E+00	.4885E-01	.0000E+00	.1264E-03	.0000E+00	.1264E-03
19.0000	.3879E-01	.0000E+00	.3879E-01	.0000E+00	.1004E-03	.0000E+00	.1004E-03
19.5000	.3150E-01	.0000E+00	.3150E-01	.0000E+00	.8153E-04	.0000E+00	.8153E-04
20.0000	.2604E-01	.0000E+00	.2604E-01	.0000E+00	.6739E-04	.0000E+00	.6739E-04

TABLE BVIII.- Continued

SPRING MASS SYSTEM

APPLIED FORCE VECTOR: FORCE AT MASS 3
RESPONSE LOCATION: MASS 2 - RESPONSE COORDINATE

MODAL ACCELERATION MATRIX A(NF,NM)
.1000E+00 -.6905E-02 -.9311E-01

SPRING MASS SYSTEM

APPLIED FORCE VECTOR: FORCE AT MASS 3
RESPONSE LOCATION: MASS 2 - RESPONSE COORDINATE

ACCELERATION MOBILITY Y(NR,NF)

N	FREQ	YR	YI
1	0.000	.1000E+00	0.
2	.500	.1001E+00	0.
3	1.000	.1005E+00	0.
4	1.500	.1012E+00	0.
5	2.000	.1021E+00	0.
6	2.500	.1033E+00	0.
7	3.000	.1049E+00	0.
8	3.500	.1068E+00	0.
9	4.000	.1092E+00	0.
10	4.500	.1122E+00	0.
11	5.000	.1158E+00	0.
12	5.500	.1205E+00	0.
13	6.000	.1269E+00	0.
14	6.500	.1364E+00	0.
15	7.000	.1547E+00	0.
16	7.500	.2310E+00	0.
17	8.000	.2237E-01	0.
18	8.500	.9959E-01	0.
19	9.000	.1212E+00	0.
20	9.500	.1361E+00	0.
21	10.000	.1500E+00	0.
22	10.500	.1649E+00	0.
23	11.000	.1822E+00	0.
24	11.500	.2033E+00	0.
25	12.000	.2301E+00	0.
26	12.500	.2658E+00	0.
27	13.000	.3158E+00	0.
28	13.500	.3916E+00	0.
29	14.000	.5199E+00	0.
30	14.500	.7844E+00	0.
31	15.000	.1647E+01	0.
32	15.500	-.1237E+02	0.
33	16.000	-.1268E+01	0.
34	16.500	-.6589E+00	0.
35	17.000	-.4411E+00	0.
36	17.500	-.3292E+00	0.
37	18.000	-.2611E+00	0.
38	18.500	-.2154E+00	0.
39	19.000	-.1826E+00	0.
40	19.500	-.1579E+00	0.
41	20.000	-.1387E+00	0.

TABLE BVIII.- Concluded

SPRING MASS SYSTEM

APPLIED FORCE VECTOR: FORCE AT MASS 3
RESPONSE LOCATION: MASS 2 - RESPONSE COORDINATE

FORCING FREQUENCY (HERTZ)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
.0000	.1000E+00	.0000E+00	.1000E+00	.0000E+00	.2588E-03	.0000E+00	.2588E-03
.5000	.1001E+00	.0000E+00	.1001E+00	.0000E+00	.2591E-03	.0000E+00	.2591E-03
1.0000	.1005E+00	.0000E+00	.1005E+00	.0000E+00	.2601E-03	.0000E+00	.2601E-03
1.5000	.1012E+00	.0000E+00	.1012E+00	.0000E+00	.2618E-03	.0000E+00	.2618E-03
2.0000	.1021E+00	.0000E+00	.1021E+00	.0000E+00	.2642E-03	.0000E+00	.2642E-03
2.5000	.1033E+00	.0000E+00	.1033E+00	.0000E+00	.2674E-03	.0000E+00	.2674E-03
3.0000	.1049E+00	.0000E+00	.1049E+00	.0000E+00	.2714E-03	.0000E+00	.2714E-03
3.5000	.1068E+00	.0000E+00	.1068E+00	.0000E+00	.2764E-03	.0000E+00	.2764E-03
4.0000	.1092E+00	.0000E+00	.1092E+00	.0000E+00	.2826E-03	.0000E+00	.2826E-03
4.5000	.1122E+00	.0000E+00	.1122E+00	.0000E+00	.2903E-03	.0000E+00	.2903E-03
5.0000	.1158E+00	.0000E+00	.1158E+00	.0000E+00	.2998E-03	.0000E+00	.2998E-03
5.5000	.1205E+00	.0000E+00	.1205E+00	.0000E+00	.3119E-03	.0000E+00	.3119E-03
6.0000	.1269E+00	.0000E+00	.1269E+00	.0000E+00	.3284E-03	.0000E+00	.3284E-03
6.5000	.1364E+00	.0000E+00	.1364E+00	.0000E+00	.3531E-03	.0000E+00	.3531E-03
7.0000	.1547E+00	.0000E+00	.1547E+00	.0000E+00	.4004E-03	.0000E+00	.4004E-03
7.5000	.2310E+00	.0000E+00	.2310E+00	.0000E+00	.5979E-03	.0000E+00	.5979E-03
8.0000	.2237E-01	.0000E+00	.2237E-01	.0000E+00	.5789E-04	.0000E+00	.5789E-04
8.5000	.9959E-01	.0000E+00	.9959E-01	.0000E+00	.2577E-03	.0000E+00	.2577E-03
9.0000	.1212E+00	.0000E+00	.1212E+00	.0000E+00	.3137E-03	.0000E+00	.3137E-03
9.5000	.1361E+00	.0000E+00	.1361E+00	.0000E+00	.3521E-03	.0000E+00	.3521E-03
10.0000	.1500E+00	.0000E+00	.1500E+00	.0000E+00	.3881E-03	.0000E+00	.3881E-03
10.5000	.1649E+00	.0000E+00	.1649E+00	.0000E+00	.4268E-03	.0000E+00	.4268E-03
11.0000	.1822E+00	.0000E+00	.1822E+00	.0000E+00	.4716E-03	.0000E+00	.4716E-03
11.5000	.2033E+00	.0000E+00	.2033E+00	.0000E+00	.5261E-03	.0000E+00	.5261E-03
12.0000	.2301E+00	.0000E+00	.2301E+00	.0000E+00	.5955E-03	.0000E+00	.5955E-03
12.5000	.2658E+00	.0000E+00	.2658E+00	.0000E+00	.6878E-03	.0000E+00	.6878E-03
13.0000	.3158E+00	.0000E+00	.3158E+00	.0000E+00	.8174E-03	.0000E+00	.8174E-03
13.5000	.3916E+00	.0000E+00	.3916E+00	.0000E+00	.1013E-02	.0000E+00	.1013E-02
14.0000	.5199E+00	.0000E+00	.5199E+00	.0000E+00	.1345E-02	.0000E+00	.1345E-02
14.5000	.7844E+00	.0000E+00	.7844E+00	.0000E+00	.2030E-02	.0000E+00	.2030E-02
15.0000	.1647E+01	.0000E+00	.1647E+01	.0000E+00	.4264E-02	.0000E+00	.4264E-02
15.5000	-.1237E+02	.0000E+00	.1237E+02	.1800E+03	-.3202E-01	.0000E+00	.3202E-01
16.0000	-.1268E+01	.0000E+00	.1268E+01	.1800E+03	-.3280E-02	.0000E+00	.3280E-02
16.5000	-.6589E+00	.0000E+00	.6589E+00	.1800E+03	-.1705E-02	.0000E+00	.1705E-02
17.0000	-.4411E+00	.0000E+00	.4411E+00	.1800E+03	-.1141E-02	.0000E+00	.1141E-02
17.5000	-.3292E+00	.0000E+00	.3292E+00	.1800E+03	-.8519E-03	.0000E+00	.8519E-03
18.0000	-.2611E+00	.0000E+00	.2611E+00	.1800E+03	-.6758E-03	.0000E+00	.6758E-03
18.5000	-.2154E+00	.0000E+00	.2154E+00	.1800E+03	-.5574E-03	.0000E+00	.5574E-03
19.0000	-.1826E+00	.0000E+00	.1826E+00	.1800E+03	-.4725E-03	.0000E+00	.4725E-03
19.5000	-.1579E+00	.0000E+00	.1579E+00	.1800E+03	-.4086E-03	.0000E+00	.4086E-03
20.0000	-.1387E+00	.0000E+00	.1387E+00	.1800E+03	-.3589E-03	.0000E+00	.3589E-03

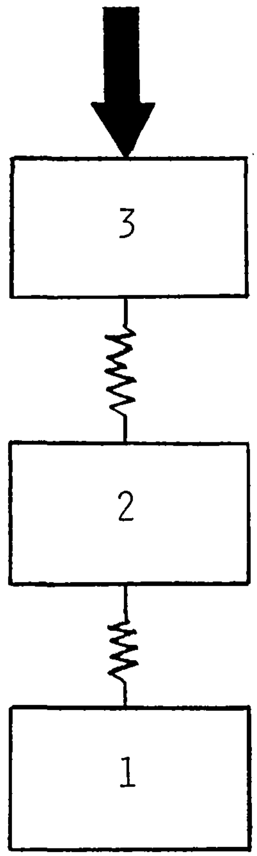


Figure B1.- Unconstrained spring mass system.

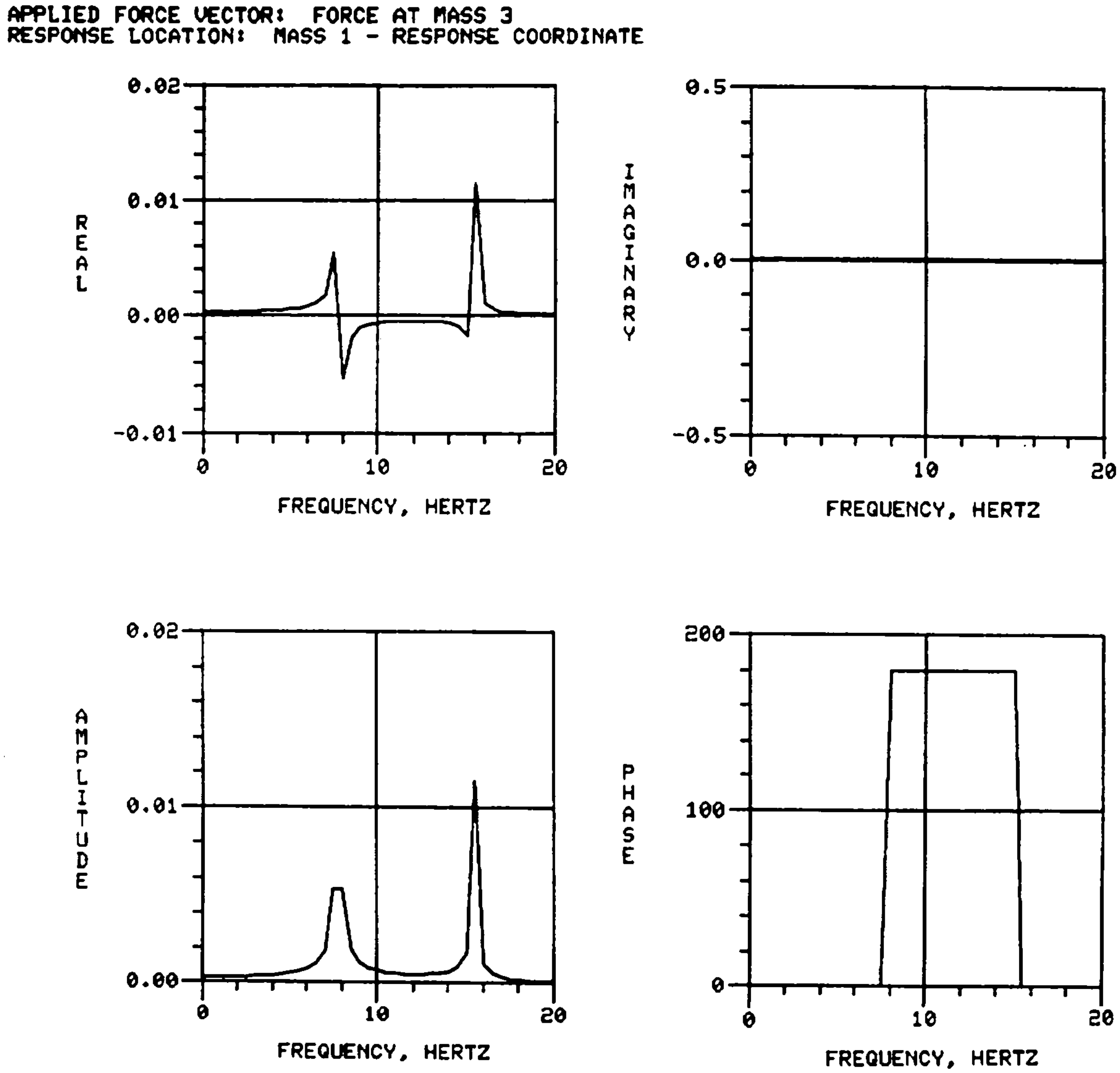


Figure B2.- Acceleration response components at mass 1.

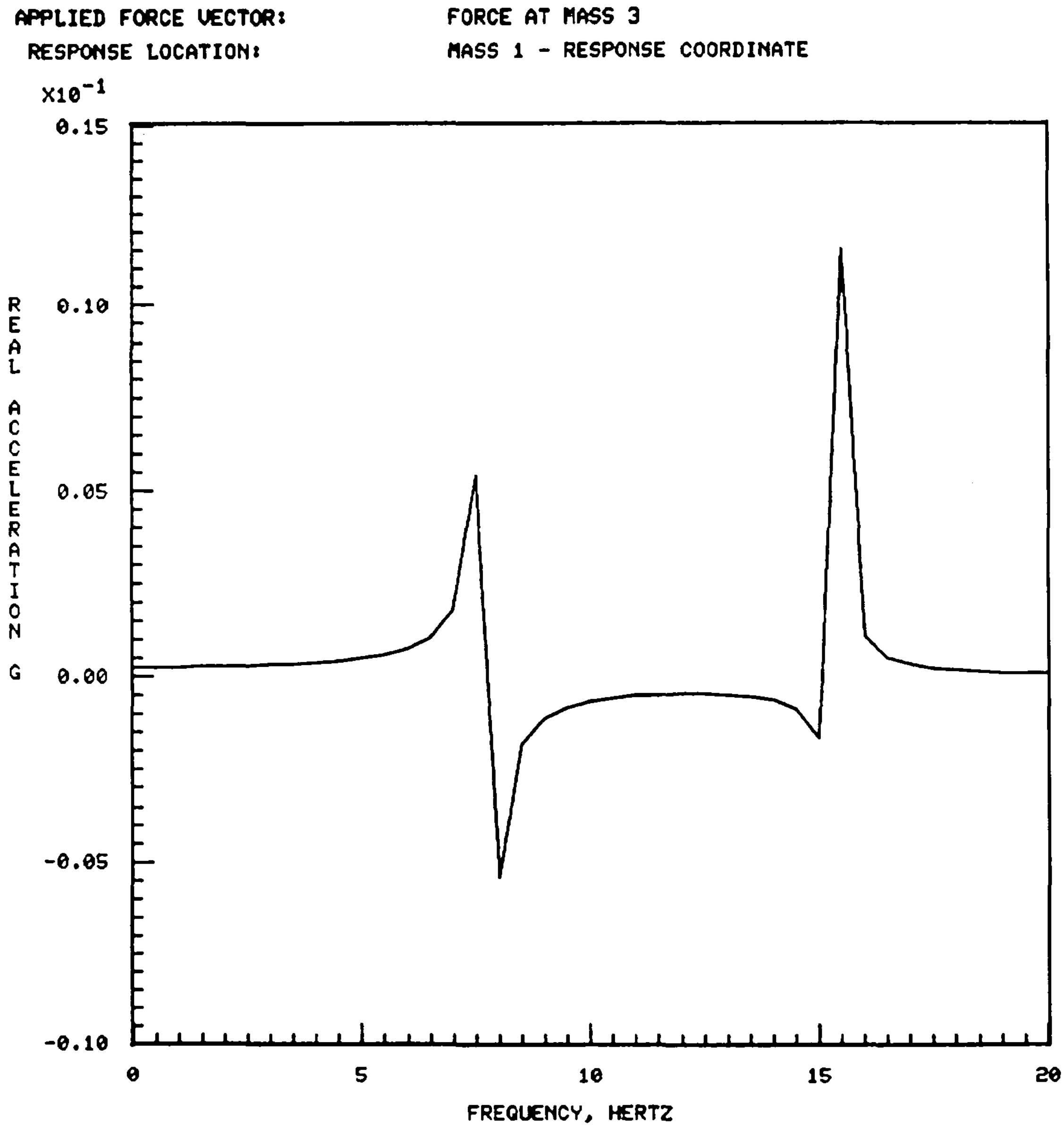


Figure B3.- Real acceleration response at mass 1.

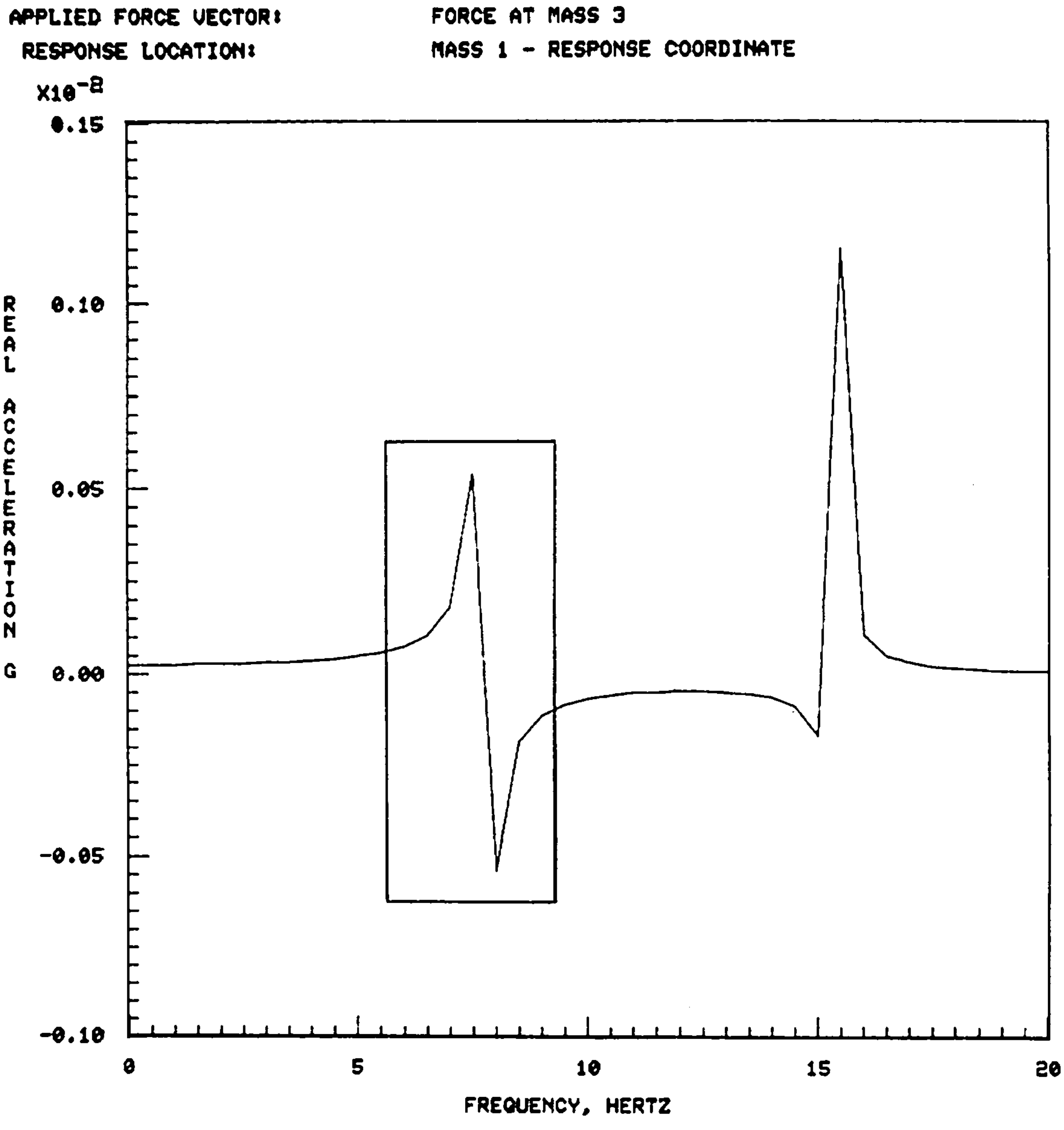


Figure B4.- Box defined by using the zoom option.

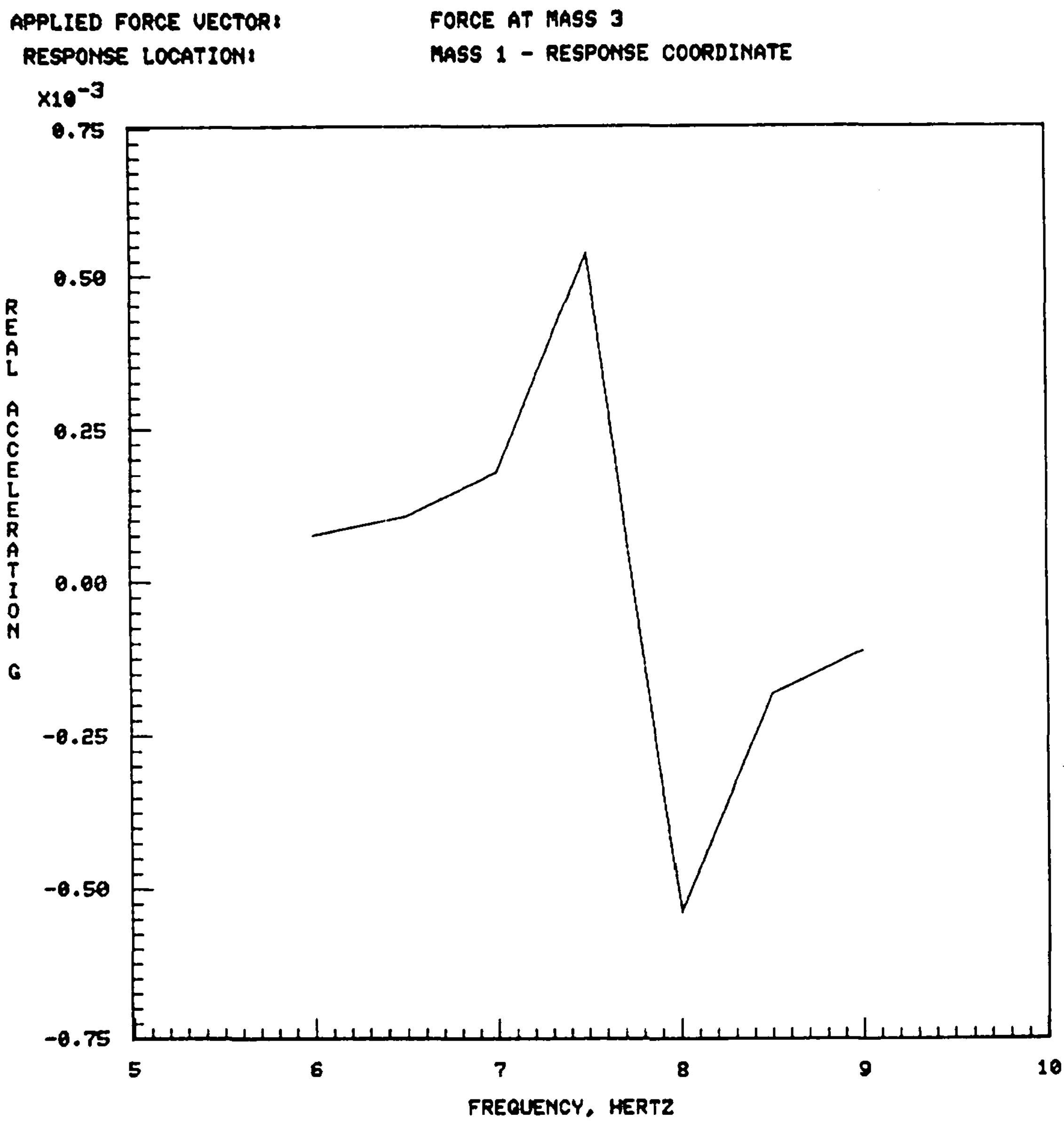


Figure B5.- Expanded plot from boxed portion shown in figure B4.

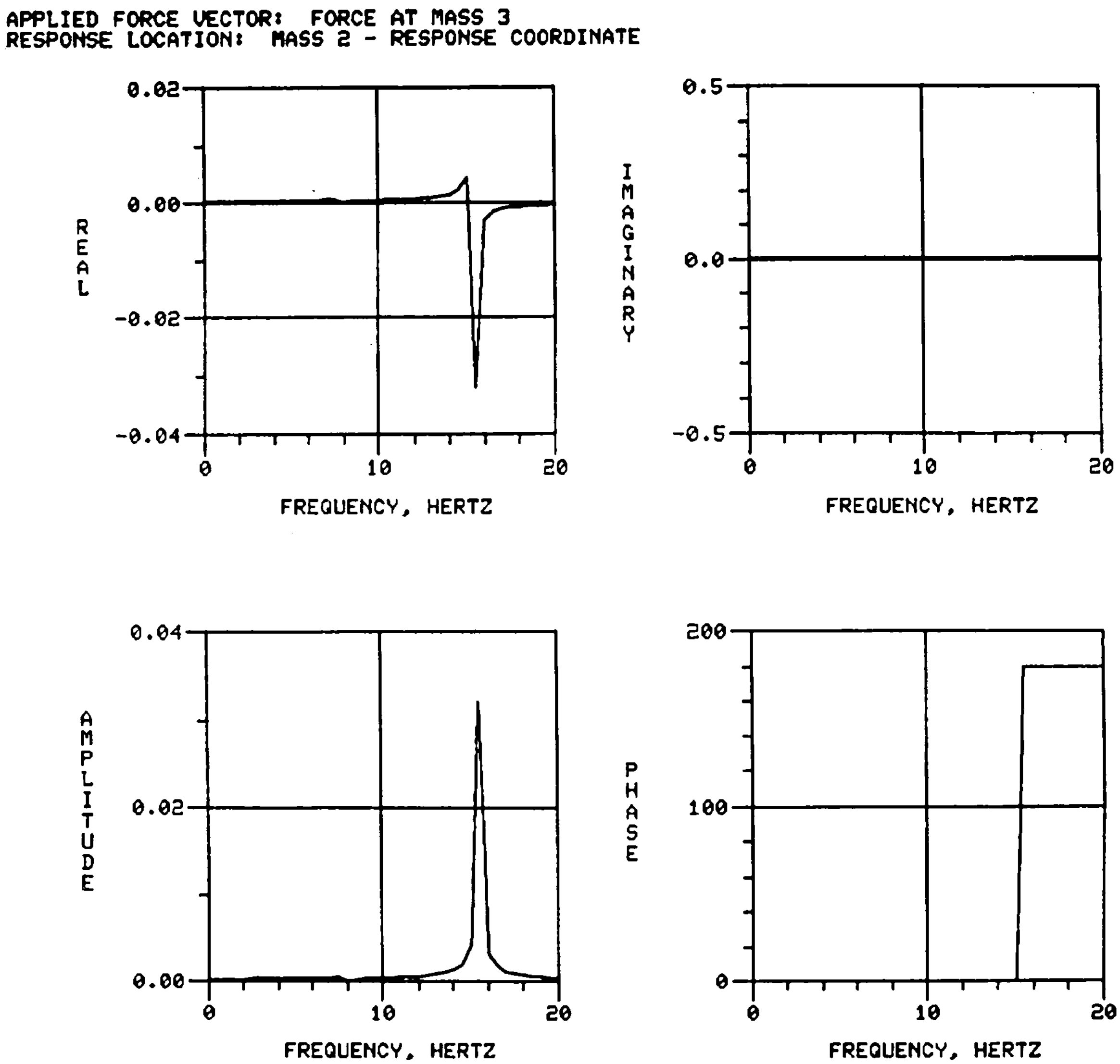


Figure B6.- Acceleration response components at mass 2.

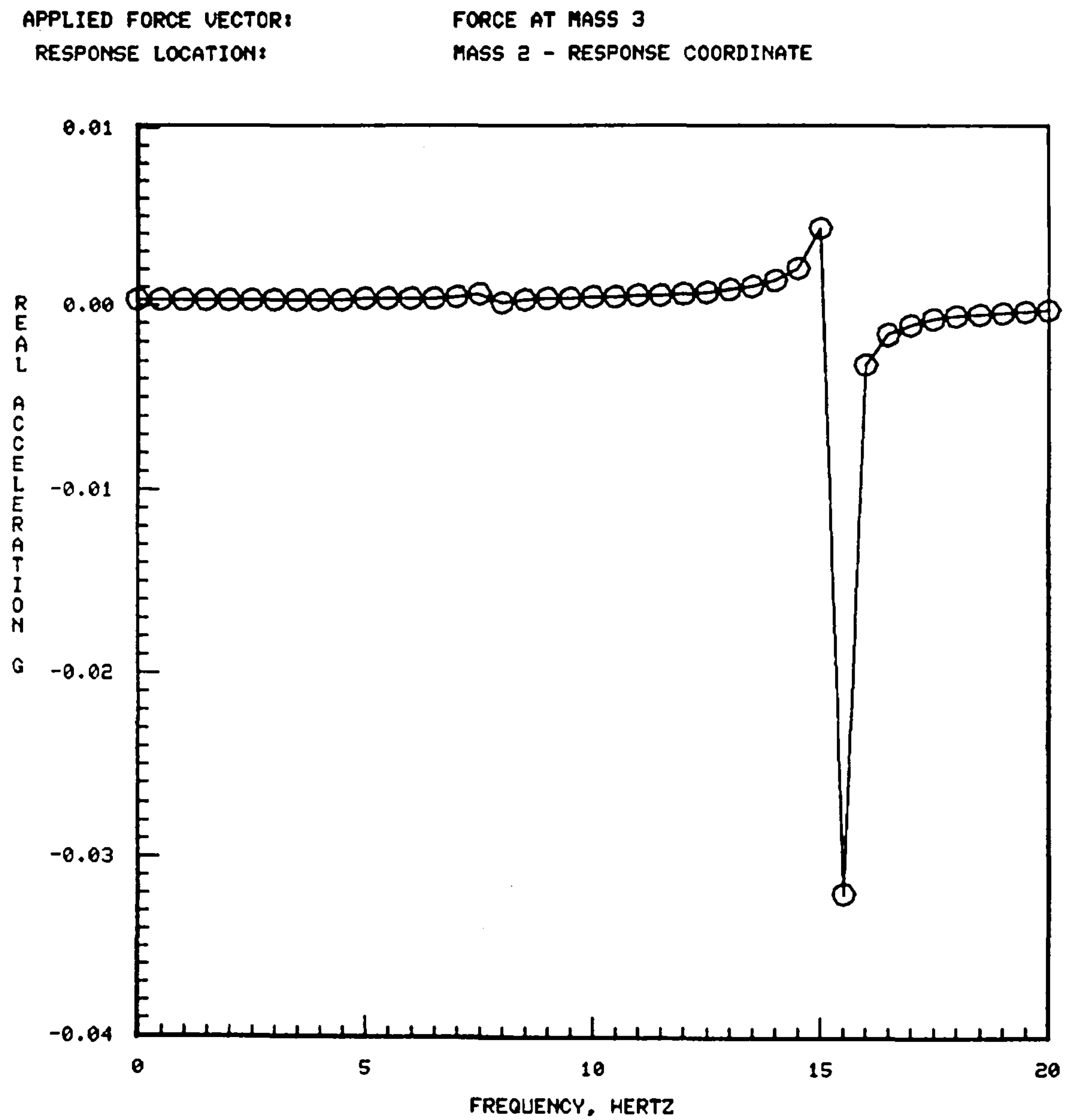


Figure B7.- Real acceleration response at mass 2.

APPENDIX C

COMPUTER REQUIREMENTS

The program VIBRA (vibration response analysis) is written in FORTRAN V for the Control Data Corporation 6600 series of computers and implemented under the NASA/LaRC Network Operating System.

Memory Allocation and Auxiliary Storage Files

VIBRA uses dynamic storage allocation for memory management of various size problems. All the arrays are packed into an array in blank common called ZZZ in the main program. The length of the blank common is set by a statement within the program. The amount of blank common memory required for a particular problem is determined by the total number of frequency points, number of natural modes, force vector sets, and force coordinate groups. The last section in appendix A contains information for estimating the length of the blank common ZZZ array. If there is insufficient blank common memory for a problem, VIBRA terminates with an error message stating the present length of array ZZZ, the problem size, and the additional amount of memory required.

In addition to using blank common, several auxiliary files are used during program execution for temporary storage and recall of intermediate calculations. Three temporary storage files, 11, 12, and 13, are suitable for saving after program execution, in addition to output file 8. Table CI gives a description of the program auxiliary files. The use of files 5, 6, 7, and 8 is demonstrated in appendix B, with input requirements for file 5 and file 7 described in appendix A. As listed in table CI, files 11, 12, and 13 contain modal acceleration, acceleration mobility, and acceleration response matrices, respectively. These files also contain index information that will enable the user to read them directly into another computer program. The format and a sample content of these files are given in tables CII to CVII.

Graphics Subroutines

VIBRA uses 37 subroutines from the PLOT-10 graphics package, which consists of the Terminal Control System (TCS), described in reference 3, and the Advanced Graphing II (AG-II), described in reference 4. Because of the LaRC Network Operating System (NOS) configuration, several TCS subroutines have been modified. The purpose of the modifications is to make the subroutines run more efficiently on the LaRC NOS. However, substitutions can be made, using equivalent TCS subroutines, to produce the same functions as the LaRC modified subroutines. The LaRC NOS modified PLOT-10 routines (ref. 5) deal with FORTRAN input/output while in graphics mode and with the file output buffer. Also, one AG-II subroutine, called LINE, was renamed ZLINE to avoid a conflict with one of the LaRC graphics system subroutines. Another LaRC NOS graphics modification involves the placement of a common block, named JTB, in the main program. This common block passes parameters to the NOS PLOT-10 system which controls the PLOT-10 vector file and the output buffer file before PLOT-10 input/output. The way these items are handled may be different, depending upon the version of PLOT-10 subroutines available on various computer systems.

APPENDIX C

Tables CVIII to CX provide lists of all the graphic subroutines used and their locations within VIBRA. The last section gives a detailed description of the LaRC modified PLOT-10 subroutines and the TCS subprograms called by them.

LaRC NOS PLOT-10 Subroutines

FORTRAN subroutines have been written for the LaRC NOS system and use a few subroutines from the TCS package. (See ref. 5.) The purpose, usage, method, and subprograms used by these NOS subroutines are described in this section. Also, a brief description of the JTB common block used in the main program is given.

Subroutine EPAUSE

Purpose: To execute a frame advance

Usage: CALL EPAUSE

Method: Terminate a plot frame and go to the next frame. A call to EPAUSE causes the following:

1. Flushes the plot vector file buffer(s)
2. Rings the terminal bell
3. Pauses
4. Continues execution when user presses return key
5. Does an immediate screen erasure

Subprograms used: TSEND, ERASE, BELL

Subroutine TPAUSE

Purpose: To dump the plot vector file buffer and pause for a user prompt

Usage: CALL TPAUSE

Method: Flush the plot vector file buffer to the terminal and pause. A call to TPAUSE causes the following:

1. Flushes the plot vector file buffer(s)
2. Rings the terminal bell
3. Pauses
4. Continues execution when user presses return key

Subprograms used: TSEND, BELL

APPENDIX C

Subroutine NOTX

Purpose: To display horizontal alphanumeric labels

Usage: CALL NOTX (IX, IY, LENCHR, ISTR), where

IX, IY	Starting position of label in screen coordinates
LENCHR	Number of characters in label (maximum of 100 characters)
ISTR	Character array name in which string is stored

Method: The PLOT-10 label routines (HLABEL, VLABEL, AND NOTAT) require labels to be stored as one character per word, ASCII decimal code. This is an inefficient way to store labels under NOS. NOTX allows user to store labels as 10 characters per word, left-justified display code. The labels are converted from display code to ASCII and are displayed by the PLOT-10 NOTAT routine.

Subprograms used: KAM2AS, NOTAT

Subroutine NOTY

Purpose: To display vertical alphanumeric labels

Usage: CALL NOTY (IX, IY, LENCHR, ISTR), where

IX, IY	Starting position of label in screen coordinates
LENCHR	Number of characters in label (maximum of 100)
ISTR	Character array name in which string is stored

Method: Same as NOTX

Subprograms used: KAM2AS, NOTAT

Subroutine DRASE

Purpose: To erase FORTRAN output from the Tektronix screen

Usage: CALL DRASE

Method: DRASE should be used (instead of ERASE OR NEWPAG) on NOS to erase FORTRAN output from the screen. This subroutine does not write an erase to the mass storage plot vector file.

Subprograms used: None

APPENDIX C

JTB Common Block

The JTB common block is located in the main program only. Default values have been taken from all the common block parameters except for JREQ.

Purpose: To control the plot vector file and output buffer

Usage: COMMON/JTB/NFR, JREQ, IBAUD, HDR, IJO, TFAC, NFLUSH, IJTB(3)

NFR	= 0 (default) Pause after a call to NFRAM and EPAUSE. Execution continues when user presses return key.
JREQ	= 2 PLOT-10 vector file is assigned to terminal and also written to file SAVPVF for saving.
IBAUD	= 120 (default) Terminal baud rate in characters/second
HDR	Used internally
IJO	Used internally
TFAC	= (4014 terminal length)/1024
NFLUSH	= 0 (default) Flush the user's output file buffer before PLOT-10 input/output
IJTB(3)	Reserved for future use

TABLE CI.- PROGRAM AUXILIARY FILES

File	Function
5	Input from keyboard
6	Output to terminal screen
7	Input data file
8	Output (results given in tabular form)
11	Modal acceleration matrices
12	Acceleration mobility matrices
13	Acceleration response matrices

TABLE CII.- AUXILIARY FILE 11 FORMAT

Card image (a)	Variable	Description	Format
1	NP	Number of problems	(I3)
2	NR NF NM	Number of responses Number of forces Number of modes	(3I4)
3	PT	Problem title card	(A80)
4	FVT	Force vector title	(A80)
5	RCT	Response coordinate title	(A80)
6	MAT	Modal acceleration heading	(A80)
7	A(NR,NF,NM)	Modal acceleration matrix	10(1X,E10.4)

[a]If there is more than one problem being solved, FILE 11 will contain card images 2 to 7 sequentially repeated NP times. Therefore, card image 1, which contains the NP variable, defines the outer loop index. The index variables on card image 2 set up the inner loop for reading NR groups of modal acceleration matrices calculated for one problem.

TABLE CIII.- FILE 11 CONTENTS FROM SAMPLE PROBLEM IN APPENDIX B

```
1
 2   1   3
  SPRING MASS SYSTEM
 APPLIED FORCE VECTOR:  FORCE AT MASS 3
 RESPONSE LOCATION:  MASS 1 - RESPONSE COORDINATE
 MODAL ACCELERATION MATRIX A(NF,NM)
.1000E+00 -.1337E+00  .3366E-01
  SPRING MASS SYSTEM
 APPLIED FORCE VECTOR:  FORCE AT MASS 3
 RESPONSE LOCATION:  MASS 2 - RESPONSE COORDINATE
 MODAL ACCELERATION MATRIX A(NF,NM)
.1000E+00 -.6905E-02 -.9311E-01
```

TABLE CIV.- AUXILIARY FILE 12 FORMAT

Card image (a)	Variable	Description	Format
1	NP	Number of problems	(I3)
2	NR NF NM	Number of responses Number of forces Number of modes	(3I4)
3	IFN	Number of frequency steps	(I3)
4	PT	Problem title card	(A80)
5	FVT	Force vector title	(A80)
6	RCT	Response coordinate title	(A80)
7	AMT1	Acceleration mobility title	(A80)
8	AMT2	Mobility heading	(A80)
9	NSTEP W(NR,NSTEP) YDD(NR,NSTEP,NF)	Frequency step number Forcing frequency Acceleration mobility matrix	(1X, I3, 1X, F8.3, 12(1X,E10.4))

[a]If there is more than one problem being solved, FILE 12 will contain card images 2 to 9 sequentially repeated NP times. Therefore, card image 1, which contains the NP variable, defines the outer loop index. The index variables on card image 2 set up the inner loop for reading NR groups of modal acceleration mobilities calculated for one problem.

TABLE CV.- FILE 12 CONTENTS FROM SAMPLE PROBLEM IN APPENDIX B

```
1
2  1
41
 .SPRING MASS SYSTEM
 APPLIED FORCE VECTOR:  FORCE AT MASS 3
 RESPONSE LOCATION:  MASS 1 - RESPONSE COORDINATE
 ACCELERATION MOBILITY Y(NR,NF)
N      FREQ      YR            YI
 1     0.000  .1000E+00 0.
 2      .500  .1005E+00 0.
 3     1.000  .1021E+00 0.
 4     1.500  .1049E+00 0.
 5     2.000  .1090E+00 0.
 6     2.500  .1146E+00 0.
 7     3.000  .1222E+00 0.
 8     3.500  .1324E+00 0.
 9     4.000  .1461E+00 0.
10     4.500  .1649E+00 0.
11     5.000  .1914E+00 0.
12     5.500  .2308E+00 0.
13     6.000  .2942E+00 0.
14     6.500  .4101E+00 0.
15     7.000  .6843E+00 0.
16     7.500  .2070E+01 0.
17     8.000 -.2077E+01 0.
18     8.500 -.7061E+00 0.
19     9.000 -.4341E+00 0.
20     9.500 -.3200E+00 0.
21    10.000 -.2589E+00 0.
22    10.500 -.2225E+00 0.
23    11.000 -.2001E+00 0.
24    11.500 -.1868E+00 0.
25    12.000 -.1806E+00 0.
26    12.500 -.1811E+00 0.
27    13.000 -.1893E+00 0.
28    13.500 -.2085E+00 0.
29    14.000 -.2481E+00 0.
30    14.500 -.3380E+00 0.
31    15.000 -.6452E+00 0.
32    15.500  .4428E+01 0.
33    16.000  .4165E+00 0.
34    16.500  .1996E+00 0.
35    17.000  .1237E+00 0.
36    17.500  .8575E-01 0.
37    18.000  .6338E-01 0.
38    18.500  .4885E-01 0.
39    19.000  .3879E-01 0.
40    19.500  .3150E-01 0.
41    20.000  .2604E-01 0.
41
  SPRING MASS SYSTEM
 APPLIED FORCE VECTOR:  FORCE AT MASS 3
 RESPONSE LOCATION:  MASS 2 - RESPONSE COORDINATE
 ACCELERATION MOBILITY Y(NR,NF)
N      FREQ      YR            YI
 1     0.000  .1000E+00 0.
 2      .500  .1001E+00 0.
 3     1.000  .1005E+00 0.
 4     1.500  .1012E+00 0.
 5     2.000  .1021E+00 0.
 6     2.500  .1033E+00 0.
 7     3.000  .1049E+00 0.
 8     3.500  .1068E+00 0.
 9     4.000  .1092E+00 0.
10     4.500  .1122E+00 0.
11     5.000  .1158E+00 0.
12     5.500  .1205E+00 0.
13     6.000  .1269E+00 0.
14     6.500  .1364E+00 0.
15     7.000  .1547E+00 0.
16     7.500  .2310E+00 0.
17     8.000  .2237E-01 0.
18     8.500  .9959E-01 0.
19     9.000  .1212E+00 0.
20     9.500  .1361E+00 0.
21    10.000  .1500E+00 0.
22    10.500  .1649E+00 0.
23    11.000  .1822E+00 0.
24    11.500  .2033E+00 0.
25    12.000  .2301E+00 0.
26    12.500  .2658E+00 0.
27    13.000  .3158E+00 0.
28    13.500  .3916E+00 0.
29    14.000  .5199E+00 0.
30    14.500  .7844E+00 0.
31    15.000  .1647E+01 0.
32    15.500 -.1237E+02 0.
33    16.000 -.1268E+01 0.
34    16.500 -.6589E+00 0.
35    17.000 -.4411E+00 0.
36    17.500 -.3292E+00 0.
37    18.000 -.2611E+00 0.
38    18.500 -.2154E+00 0.
39    19.000 -.1826E+00 0.
40    19.500 -.1579E+00 0.
41    20.000 -.1387E+00 0.
```

TABLE CVI.- AUXILIARY FILE 13 FORMAT

Card image (a)	Variable	Description	Format
1	NP	Number of problems	(I3)
2	NR	Number of responses	(I3)
3	IFN	Number of frequency steps	(I3)
4	PT	Problem title	(A80)
5	FVT	Force vector title	(A80)
6	RCT	Response coordinate title	(A80)
7	ART	Acceleration response heading	(A80)
8	NSTEP W(NR,NSTEP) QDD(NR,NSTEP)	Frequency step number Forcing frequency Complex acceleration response	(1X, I3, 1X, F8.3, 2(1X,E10.4))

[a]If there is more than one problem being solved, FILE 13 will contain card images 2 to 8 sequentially repeated NP times. Therefore, card image 1, which contains the NP variable, defines the outer loop index. The index variables on card image 2 set up the inner loop for reading NR groups of acceleration response tables calculated for one problem.

APPENDIX C

TABLE CVII.- FILE 13 CONTENTS FROM SAMPLE PROBLEM IN APPENDIX B

```
 1
 2
41
   SPRING MASS SYSTEM
  APPLIED FORCE VECTOR:  FORCE AT MASS 3
  RESPONSE LOCATION:  MASS 1 - RESPONSE COORDINATE
 N     FREQ      QR          QI
  1     0.000  .1000E+00 0.
  2      .500  .1005E+00 0.
  3     1.000  .1021E+00 0.
  4     1.500  .1049E+00 0.
  5     2.000  .1090E+00 0.
  6     2.500  .1146E+00 0.
  7     3.000  .1222E+00 0.
  8     3.500  .1324E+00 0.
  9     4.000  .1461E+00 0.
 10     4.500  .1649E+00 0.
 11     5.000  .1914E+00 0.
 12     5.500  .2308E+00 0.
 13     6.000  .2942E+00 0.
 14     6.500  .4101E+00 0.
 15     7.000  .6843E+00 0.
 16     7.500  .2070E+01 0.
 17     8.000 -.2077E+01 0.
 18     8.500 -.7061E+00 0.
 19     9.000 -.4341E+00 0.
 20     9.500 -.3200E+00 0.
 21    10.000 -.2589E+00 0.
 22    10.500 -.2225E+00 0.
 23    11.000 -.2001E+00 0.
 24    11.500 -.1868E+00 0.
 25    12.000 -.1806E+00 0.
 26    12.500 -.1811E+00 0.
 27    13.000 -.1893E+00 0.
 28    13.500 -.2085E+00 0.
 29    14.000 -.2481E+00 0.
 30    14.500 -.3380E+00 0.
 31    15.000 -.6452E+00 0.
 32    15.500  .4428E+01 0.
 33    16.000  .4165E+00 0.
 34    16.500  .1996E+00 0.
 35    17.000  .1237E+00 0.
 36    17.500  .8575E-01 0.
 37    18.000  .6338E-01 0.
 38    18.500  .4885E-01 0.
 39    19.000  .3879E-01 0.
 40    19.500  .3150E-01 0.
 41    20.000  .2604E-01 0.
41
   SPRING MASS SYSTEM
  APPLIED FORCE VECTOR:  FORCE AT MASS 3
  RESPONSE LOCATION:  MASS 2 - RESPONSE COORDINATE
 N     FREQ      QR          QI
  1     0.000  .1000E+00 0.
  2      .500  .1001E+00 0.
  3     1.000  .1005E+00 0.
  4     1.500  .1012E+00 0.
  5     2.000  .1021E+00 0.
  6     2.500  .1033E+00 0.
  7     3.000  .1049E+00 0.
  8     3.500  .1068E+00 0.
  9     4.000  .1092E+00 0.
 10     4.500  .1122E+00 0.
 11     5.000  .1158E+00 0.
 12     5.500  .1205E+00 0.
 13     6.000  .1269E+00 0.
 14     6.500  .1364E+00 0.
 15     7.000  .1547E+00 0.
 16     7.500  .2310E+00 0.
 17     8.000  .2237E-01 0.
 18     8.500  .9959E-01 0.
 19     9.000  .1212E+00 0.
 20     9.500  .1361E+00 0.
 21    10.000  .1500E+00 0.
 22    10.500  .1649E+00 0.
 23    11.000  .1822E+00 0.
 24    11.500  .2033E+00 0.
 25    12.000  .2301E+00 0.
 26    12.500  .2658E+00 0.
 27    13.000  .3158E+00 0.
 28    13.500  .3916E+00 0.
 29    14.000  .5199E+00 0.
 30    14.500  .7844E+00 0.
 31    15.000  .1647E+01 0.
 32    15.500 -.1237E+02 0.
 33    16.000 -.1268E+01 0.
 34    16.500 -.6589E+00 0.
 35    17.000 -.4411E+00 0.
 36    17.500 -.3292E+00 0.
 37    18.000 -.2611E+00 0.
 38    18.500 -.2154E+00 0.
 39    19.000 -.1826E+00 0.
 40    19.500 -.1579E+00 0.
 41    20.000 -.1387E+00 0.
```

TABLE CVIII.- PLOT-10 GRAPHICS SUBROUTINES USED IN VIBRA

TCS subroutines	AG-II subroutines
ANMODE	BINITT
CHRSIZ	CHECK
DRAWA	DLIMX
ERASE	DLIMY
FINITT	DSPLAY
INITT	FRAME
MOVABS	NPTS
MOVEA	SIZES
TERM	SLIMX
TSEND	SLIMY
VCURSR	STEPS
	SYMBL
LaRC subroutines	XFRM
	XMFRM
EPAUSE	XMTCS
TPAUSE	XNEAT
NOTX	YFRM
NOTY	YMFRM
DRASE	YMTCS
	YNEAT
	ZLINE (ZLINE is actually LINE in AG-II)

TABLE CIX.- PLOT-10 SUBROUTINE LOCATION WITHIN VIBRA

PLOT-10 subroutine	Location in VIBRA subroutines
ANMODE	MAIN GRAFIT QUAD4 ALABELS
BINITT	MAIN TKSET QUAD4 QRPV QIPV AMPV PHPV
CHECK	GRAFIT QRPV QIPV AMPV PHPV ZOOM
CHRSIZ	MAIN TKSET QRPV QIPV AMPV PHPV
DLIMX	GRAFIT ZOOM
DLIMY	GRAFIT ZOOM
DRASE[a]	MAIN PAUSE
DRAWA	ZOOM
DSPLAY	GRAFIT QRPV QIPV AMPV PHPV ZOOM
EPAUSE[a]	MAIN GRAFIT QUAD4 ALABELS
ERASE	TKSET QUAD4
FINITT	MAIN
FRAME	TKSET
INITT	MAIN
MOVABS	MAIN GRAFIT QUAD4 ALABELS
MOVEA	ZOOM
NOTX[a]	QRPV QIPV AMPV PHPV ALABELS
NOTY[a]	QRPV QIPV AMPV PHPV ALABELS
NPTS	GRAFIT QRPV QIPV AMPV PHPV ZOOM
SIZES	TKSET
SLIMX	TKSET QRPV QIPV AMPV PHPV
SLIMY	TKSET QRPV QIPV AMPV PHPV
STEPS	TKSET
SYMBL	TKSET QUAD4
TERM	MAIN TKSET QUAD4
TPAUSE[a]	PAUSE
TSEND	GRAFIT QUAD4 ALABELS
VCURSR	ZOOM
XFRM	TKSET
XMFRM	TKSET
XMTCS	TKSET
XNEAT	TKSET QUAD4
YFRM	TKSET
YMFRM	TKSET
YMTCS	TKSET
YNEAT	TKSET QUAD4
ZLINE[b]	TKSET QUAD4

[a]LaRC NOS PLOT-10 subroutine.
[b]NOS modified name; AG-II name is LINE.

TABLE CX.- VIBRA SUBROUTINES THAT USE PLOT-10 SUBROUTINES

VIBRA subroutine	PLOT-10 subroutines
MAIN	ANMODE BINITT CHRSIZ DRASE[a] EPAUSE[a] FINITT INITT MOVABS TERM
PAUSE	TPAUSE DRASE[a]
GRAFIT	ANMODE CHECK DLIMX DLIMY DSPLAY EPAUSE[a] FRAME MOVABS NPTS SLIMX SLIMY TSEND
TKSET	BINITT CHRSIZ ERASE SIZES STEPS SYMBL TERM XFRM XMFRM XMTCS XNEAT YFRM YMFRM YMTCS YNEAT ZLINE[b]
QUAD4	ANMODE BINITT CHRSIZ ERASE MOVABS SYMBL TERM TSEND XNEAT YNEAT ZLINE[b]
QRPV QIPV AMPV PHPV	BINITT CHECK DSPLAY NOTX[a] NOTY[a] NPTS SLIMX SLIMY
ZOOM	CHECK DLIMX DLIMY DRAWA DSPLAY EPAUSE[a] NPTS FRAME MOVEA VCURSR XNEAT YNEAT
ALABELS	ANMODE MOVEABS NOTX[a] NOTY[a] TSEND

[a]LaRC NOS PLOT-10 subroutine.
[b]NOS modified name; AG-II name is LINE.

REFERENCES

1. The NASTRAN® Theoretical Manual. NASA SP-221(06), 1981.

2. Flannelly, W. G.; Fabunmi, J. A.; and Nagy, E. J.: Analytical Testing. NASA CR-3429, 1981.

3. PLOT-10 Terminal Control System - User's Manual. Doc. No. 062-1474-00, Tektronix, Inc., c.1974 (Reprinted Dec. 1976).

4. PLOT-10 Advanced Graphing II - User's Manual. Doc. No. 062-1530-00, Tektronix, Inc., c.1973 (Reprinted Dec. 1976).

5. Computer Programing Manual. Volume IV - Special Capabilities. NASA Langley Research Center, Apr. 30, 1980.

TABLE I.- MODAL DATA FOR UNDAMPED SYSTEM FOR CASE 1

Mode	Frequency, Hz	Generalized mass	Mode shape				
1	6.01	4.48	1.0	0.857	0.694	0.470	0.302
2	14.05	1.84	-1.0	-.221	.298	.373	.273
3	22.13	6.87	1.0	.934	-.547	.944	.926
4	27.51	2.87	-.503	1.0	-.489	.233	.317
5	42.47	2.24	.00362	-.0221	.0829	-.536	1.0

TABLE II.- INPUT DATA FILE 7 FOR CASE 1A

```
TEST CASE 1A FOR VIBRA ---CONSTRAINED SYSTEM---
0 5  0  1  1  1  1  0.0  50.0  1.
NATURAL FREQUENCY (HZ)
6.01  14.05  22.13  27.51  42.47
GENERALIZED MASS
4.48  1.84  6.87  2.87  2.24
 VISCOUS DAMPING
.025
FORCE AT NODE 1
(1.0,0.0)
NODE 1 MODE SHAPE FOR FORCE AT NODE 1
1.00  -1.00  1.00  -.503  .00362
RESPONSE AT NODE 1
1.00  -1.00  1.00  -.503  .00362
RESPONSE AT NODE 5
.302  .273  .926  .317  1.00
```

TABLE III.- CONTROL PARAMETER DESCRIPTION FOR CASE 1A

```
                TEST CASE 1A FOR VIBRA ---CONSTRAINED SYSTEM---


CONTROL PARAMETERS SET

NZ     =  0 *RIGID BODY MODES*
NM     =  5 *MODES TOTAL*
MNORM  =  0 *NORMAL MODES*
MDAMP  =  1 *VISCOUS DAMPING*
NZETA  =  1 *DAMPING IS CONSTANT*
NFS    =  1 *FORCE VECTOR SETS*
NF     =  1 *FORCE COORDINATES*
WSTRT  =    .0 *STARTING FREQUENCY (HZ) *
WSTOP  =  50.0 *STOPPING FREQUENCY (HZ) *
DELW   =   1.000 *FREQUENCY STEP*

          BLANK COMMON STORAGE ZZZ REQUIRES    351 LOCATIONS

          NOW COMPUTING FORCED RESPONSE
```

TABLE IV.- ACCELERATION RESPONSE AT NODE 1

TEST CASE 1A FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: FORCE AT NODE 1
RESPONSE LOCATION: RESPONSE AT NODE 1

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
0.0000	0.	0.	0.	0.	0.	0.	0.
1.0000	-.9537E-02	.6516E-04	.9537E-02	.1796E+03	-.2468E-04	.1686E-06	.2468E-04
2.0000	-.4069E-01	.6088E-03	.4070E-01	.1791E+03	-.1053E-03	.1575E-05	.1053E-03
3.0000	-.1037E+00	.2775E-02	.1038E+00	.1785E+03	-.2685E-03	.7181E-05	.2686E-03
4.0000	-.2316E+00	.1137E-01	.2319E+00	.1772E+03	-.5994E-03	.2942E-04	.6001E-03
5.0000	-.5824E+00	.6832E-01	.5864E+00	.1733E+03	-.1507E-02	.1768E-03	.1518E-02
6.0000	-.4327E+00	.4441E+01	.4462E+01	.9556E+02	-.1120E-02	.1149E-01	.1155E-01
7.0000	.6256E+00	.1414E+00	.6414E+00	.1274E+02	.1619E-02	.3659E-03	.1660E-02
8.0000	.2183E+00	.5541E-01	.2253E+00	.1424E+02	.5650E-03	.1434E-03	.5830E-03
9.0000	-.1506E-01	.4557E-01	.4799E-01	.1083E+03	-.3898E-04	.1179E-03	.1242E-03
10.0000	-.2572E+00	.5778E-01	.2636E+00	.1673E+03	-.6655E-03	.1495E-03	.6821E-03
11.0000	-.5988E+00	.1005E+00	.6071E+00	.1705E+03	-.1550E-02	.2601E-03	.1571E-02
12.0000	-.1213E+01	.2385E+00	.1237E+01	.1689E+03	-.3140E-02	.6174E-03	.3201E-02
13.0000	-.2749E+01	.9549E+00	.2910E+01	.1608E+03	-.7114E-02	.2471E-02	.7531E-02
14.0000	-.1368E+01	.1063E+02	.1072E+02	.9733E+02	-.3540E-02	.2751E-01	.2773E-01
15.0000	.3972E+01	.1492E+01	.4243E+01	.2059E+02	.1028E-01	.3862E-02	.1098E-01
16.0000	.2346E+01	.4589E+00	.2391E+01	.1107E+02	.6072E-02	.1188E-02	.6187E-02
17.0000	.1679E+01	.2472E+00	.1697E+01	.8374E+01	.4345E-02	.6397E-03	.4392E-02
18.0000	.1282E+01	.1797E+00	.1295E+01	.7981E+01	.3318E-02	.4652E-03	.3350E-02
19.0000	.9617E+00	.1718E+00	.9769E+00	.1013E+02	.2489E-02	.4445E-03	.2528E-02
20.0000	.6033E+00	.2365E+00	.6480E+00	.2141E+02	.1561E-02	.6121E-03	.1677E-02
21.0000	.2811E-01	.5860E+00	.5867E+00	.8725E+02	.7275E-04	.1517E-02	.1518E-02
22.0000	.3556E+00	.2812E+01	.2834E+01	.8279E+02	.9204E-03	.7277E-02	.7335E-02
23.0000	.2285E+01	.9685E+00	.2481E+01	.2297E+02	.5913E-02	.2507E-02	.6422E-02
24.0000	.1679E+01	.3629E+00	.1718E+01	.1219E+02	.4346E-02	.9391E-03	.4446E-02
25.0000	.1284E+01	.2697E+00	.1312E+01	.1186E+02	.3323E-02	.6981E-03	.3396E-02
26.0000	.9015E+00	.3848E+00	.9802E+00	.2311E+02	.2333E-02	.9958E-03	.2537E-02
27.0000	.5857E+00	.1193E+01	.1329E+01	.6385E+02	.1516E-02	.3087E-02	.3439E-02
28.0000	.2189E+01	.1265E+01	.2528E+01	.3002E+02	.5664E-02	.3273E-02	.6542E-02
29.0000	.2007E+01	.3972E+00	.2046E+01	.1119E+02	.5195E-02	.1028E-02	.5296E-02
30.0000	.1757E+01	.1964E+00	.1768E+01	.6378E+01	.4547E-02	.5082E-03	.4575E-02
31.0000	.1608E+01	.1263E+00	.1613E+01	.4492E+01	.4162E-02	.3269E-03	.4175E-02
32.0000	.1511E+01	.9314E-01	.1514E+01	.3528E+01	.3910E-02	.2410E-03	.3917E-02
33.0000	.1441E+01	.7424E-01	.1443E+01	.2949E+01	.3730E-02	.1921E-03	.3735E-02
34.0000	.1389E+01	.6214E-01	.1390E+01	.2562E+01	.3595E-02	.1608E-03	.3598E-02
35.0000	.1348E+01	.5374E-01	.1349E+01	.2284E+01	.3487E-02	.1391E-03	.3490E-02
36.0000	.1314E+01	.4755E-01	.1315E+01	.2073E+01	.3400E-02	.1231E-03	.3403E-02
37.0000	.1286E+01	.4280E-01	.1287E+01	.1906E+01	.3328E-02	.1108E-03	.3330E-02
38.0000	.1262E+01	.3903E-01	.1263E+01	.1771E+01	.3266E-02	.1010E-03	.3268E-02
39.0000	.1242E+01	.3596E-01	.1242E+01	.1659E+01	.3214E-02	.9306E-04	.3215E-02
40.0000	.1224E+01	.3341E-01	.1224E+01	.1563E+01	.3168E-02	.8645E-04	.3169E-02
41.0000	.1208E+01	.3126E-01	.1209E+01	.1482E+01	.3127E-02	.8089E-04	.3129E-02
42.0000	.1195E+01	.2945E-01	.1195E+01	.1412E+01	.3092E-02	.7621E-04	.3093E-02
43.0000	.1182E+01	.2782E-01	.1183E+01	.1348E+01	.3060E-02	.7201E-04	.3061E-02
44.0000	.1171E+01	.2634E-01	.1172E+01	.1288E+01	.3032E-02	.6817E-04	.3033E-02
45.0000	.1162E+01	.2505E-01	.1162E+01	.1236E+01	.3006E-02	.6483E-04	.3007E-02
46.0000	.1152E+01	.2391E-01	.1153E+01	.1189E+01	.2983E-02	.6188E-04	.2983E-02
47.0000	.1144E+01	.2289E-01	.1145E+01	.1146E+01	.2961E-02	.5923E-04	.2962E-02
48.0000	.1137E+01	.2196E-01	.1137E+01	.1107E+01	.2942E-02	.5683E-04	.2943E-02
49.0000	.1130E+01	.2111E-01	.1130E+01	.1071E+01	.2924E-02	.5464E-04	.2925E-02
50.0000	.1124E+01	.2034E-01	.1124E+01	.1037E+01	.2908E-02	.5264E-04	.2908E-02

TABLE V.- ACCELERATION RESPONSE AT NODE 5

TEST CASE 1A FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: FORCE AT NODE 1
RESPONSE LOCATION: RESPONSE AT NODE 5

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
0.0000	0.	0.	0.	0.	0.	0.	0.
1.0000	-.1367E-02	.1421E-04	.1367E-02	.1794E+03	-.3538E-05	.3678E-07	.3538E-05
2.0000	-.6142E-02	.1387E-03	.6143E-02	.1787E+03	-.1589E-04	.3590E-06	.1590E-04
3.0000	-.1712E-01	.6773E-03	.1714E-01	.1777E+03	-.4431E-04	.1753E-05	.4435E-04
4.0000	-.4370E-01	.3022E-02	.4380E-01	.1760E+03	-.1131E-03	.7821E-05	.1134E-03
5.0000	-.1327E+00	.1974E-01	.1342E+00	.1715E+03	-.3434E-03	.5109E-04	.3472E-03
6.0000	-.6414E-01	.1339E+01	.1341E+01	.9274E+02	-.1660E-03	.3466E-02	.3470E-02
7.0000	.2875E+00	.3939E-01	.2902E+00	.7799E+01	.7442E-03	.1019E-03	.7511E-03
8.0000	.2095E+00	.1059E-01	.2097E+00	.2895E+01	.5421E-03	.2741E-04	.5428E-03
9.0000	.2041E+00	.2243E-02	.2041E+00	.6298E+00	.5281E-03	.5805E-05	.5281E-03
10.0000	.2306E+00	-.5171E-02	.2307E+00	-.1284E+01	.5969E-03	-.1338E-04	.5970E-03
11.0000	.2948E+00	-.1858E-01	.2954E+00	-.3606E+01	.7630E-03	-.4808E-04	.7645E-03
12.0000	.4371E+00	-.5681E-01	.4408E+00	-.7406E+01	.1131E-02	-.1470E-03	.1141E-02
13.0000	.8307E+00	-.2521E+00	.8681E+00	-.1688E+02	.2150E-02	-.6523E-03	.2247E-02
14.0000	.4253E+00	-.2892E+01	.2923E+01	-.8163E+02	.1101E-02	-.7484E-02	.7564E-02
15.0000	-.1066E+01	-.3949E+00	.1137E+01	-.1597E+03	-.2760E-02	-.1022E-02	.2943E-02
16.0000	-.6655E+00	-.1083E+00	.6742E+00	-.1708E+03	-.1722E-02	-.2804E-03	.1745E-02
17.0000	-.5417E+00	-.4214E-01	.5434E+00	-.1756E+03	-.1402E-02	-.1090E-03	.1406E-02
18.0000	-.5188E+00	-.7276E-02	.5188E+00	-.1792E+03	-.1343E-02	-.1883E-04	.1343E-02
19.0000	-.5685E+00	.3158E-01	.5693E+00	.1768E+03	-.1471E-02	.8174E-04	.1473E-02
20.0000	-.7224E+00	.1159E+00	.7316E+00	.1709E+03	-.1869E-02	.3000E-03	.1893E-02
21.0000	-.1112E+01	.4517E+00	.1200E+01	.1579E+03	-.2877E-02	.1169E-02	.3105E-02
22.0000	-.6786E+00	.2516E+01	.2606E+01	.1051E+03	-.1756E-02	.6511E-02	.6743E-02
23.0000	.1241E+01	.8008E+00	.1477E+01	.3284E+02	.3211E-02	.2073E-02	.3822E-02
24.0000	.8393E+00	.2128E+00	.8658E+00	.1423E+02	.2172E-02	.5506E-03	.2241E-02
25.0000	.6987E+00	.4996E-01	.7004E+00	.4090E+01	.1808E-02	.1293E-03	.1813E-02
26.0000	.7274E+00	-.1053E+00	.7350E+00	-.8237E+01	.1883E-02	-.2725E-03	.1902E-02
27.0000	.7942E+00	-.6548E+00	.1029E+01	-.3951E+02	.2055E-02	-.1695E-02	.2664E-02
28.0000	-.3064E+00	-.7230E+00	.7852E+00	-.1130E+03	-.7929E-03	-.1871E-02	.2032E-02
29.0000	-.2578E+00	-.1907E+00	.3207E+00	-.1435E+03	-.6672E-03	-.4936E-03	.8300E-03
30.0000	-.1499E+00	-.7399E-01	.1672E+00	-.1537E+03	-.3880E-03	-.1915E-03	.4326E-03
31.0000	-.9550E-01	-.3689E-01	.1024E+00	-.1589E+03	-.2471E-03	-.9547E-04	.2649E-03
32.0000	-.6598E-01	-.2123E-01	.6931E-01	-.1622E+03	-.1708E-03	-.5495E-04	.1794E-03
33.0000	-.4857E-01	-.1337E-01	.5038E-01	-.1646E+03	-.1257E-03	-.3461E-04	.1304E-03
34.0000	-.3767E-01	-.8932E-02	.3871E-01	-.1667E+03	-.9748E-04	-.2312E-04	.1002E-03
35.0000	-.3058E-01	-.6178E-02	.3119E-01	-.1686E+03	-.7913E-04	-.1599E-04	.8073E-04
36.0000	-.2592E-01	-.4307E-02	.2627E-01	-.1706E+03	-.6708E-04	-.1115E-04	.6800E-04
37.0000	-.2295E-01	-.2883E-02	.2313E-01	-.1728E+03	-.5940E-04	-.7461E-05	.5987E-04
38.0000	-.2133E-01	-.1591E-02	.2139E-01	-.1757E+03	-.5520E-04	-.4118E-05	.5535E-04
39.0000	-.2097E-01	-.5679E-04	.2097E-01	-.1798E+03	-.5427E-04	-.1470E-06	.5427E-04
40.0000	-.2207E-01	.2531E-02	.2222E-01	.1735E+03	-.5712E-04	.6550E-05	.5750E-04
41.0000	-.2464E-01	.8792E-02	.2616E-01	.1604E+03	-.6376E-04	.2275E-04	.6770E-04
42.0000	-.2070E-01	.2527E-01	.3267E-01	.1293E+03	-.5358E-04	.6539E-04	.8454E-04
43.0000	.5080E-02	.2505E-01	.2556E-01	.7853E+02	.1315E-04	.6482E-04	.6614E-04
44.0000	.8557E-02	.1008E-01	.1322E-01	.4968E+02	.2215E-04	.2609E-04	.3422E-04
45.0000	.5847E-02	.4446E-02	.7346E-02	.3725E+02	.1513E-04	.1151E-04	.1901E-04
46.0000	.3866E-02	.2286E-02	.4492E-02	.3060E+02	.1001E-04	.5917E-05	.1162E-04
47.0000	.2629E-02	.1296E-02	.2931E-02	.2624E+02	.6804E-05	.3354E-05	.7585E-05
48.0000	.1840E-02	.7773E-03	.1997E-02	.2290E+02	.4762E-05	.2012E-05	.5169E-05
49.0000	.1318E-02	.4792E-03	.1402E-02	.1998E+02	.3410E-05	.1240E-05	.3629E-05
50.0000	.9601E-03	.2961E-03	.1005E-02	.1714E+02	.2485E-05	.7663E-06	.2600E-05

TABLE VI.- FORCE VECTOR SETS FOR CASE 1B

Vector set	Mass location	Force magnitude	
		Real	Imaginary
1	1	100	-50
	2	-50	-200
	3	150	150
2	1	50	-50
	2	250	-100
	3	-100	50

TABLE VII.- MODAL DAMPING DATA FOR CASE 1B

Mode	Viscous damping, ζ
1	0.025
2	.04
3	.018
4	.02
5	.06

TABLE VIII.- INPUT DATA FILE 7 FOR CASE 1B

```
TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---
0 5  0  1  0  2  3  20.0 20.0  0.
NATURAL FREQUENCY (HZ)
6.01  14.05  22.13  27.51  42.47
GENERALIZED MASS
 4.48  1.84  6.87  2.87  2.24
 VISCOUS DAMPING
.025  .04  .018  .02  .06
 *FORCE VECTOR SET 1*
 (100,-50)  (-50,-200)  (150,150)
 *FORCE VECTOR SET 2*
 (50,-50)  (250,-100)  (-100,50)
NODE 1 MODE SHAPE FOR FORCE AT NODE 1
  1.00  -1.00  1.00  -.503  .00362
NODE 2 MODE SHAPE FOR FORCE AT NODE 2
 .857  -.221  -.934  1.00  -.0221
NODE 3 MODE SHAPE FOR FORCE AT NODE 3
 .694  .298  -.547  -.489  .0829
 RESPONSE AT NODE 1
  1.00  -1.00  1.00  -.503  .00362
 RESPONSE AT NODE 2
 .857  -.221  -.934  1.00  -.0221
 RESPONSE AT NODE3
 .694  .298  -.547  -.489  .0829
 RESPONSE AT NODE 4
 .470  .373  .944  .223  -.536
 RESPONSE AT NODE 5
 .302  .273  .926  .317  1.00
```

TABLE IX.- CONTROL PARAMETERS DESCRIPTION FOR CASE 1B

```
                TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

CONTROL PARAMETERS SET

NZ     =   0 *RIGID BODY MODES*
NM     =   5 *MODES TOTAL*
MNORM  =   0 *NORMAL MODES*
MDAMP  =   1 *VISCOUS DAMPING*
NZETA  =   0 *DAMPING VARIES*
NFS    =   2 *FORCE VECTOR SETS*
NF     =   3 *FORCE COORDINATES*
WSTRT  =  20.0 *STARTING FREQUENCY (HZ) *
WSTOP  =  20.0 *STOPPING FREQUENCY (HZ) *
DELW   =    .000 *FREQUENCY STEP*

       BLANK COMMON STORAGE ZZZ REQUIRES      79 LOCATIONS

       NOW COMPUTING FORCED RESPONSE
```

TABLE X.- MODAL ACCELERATION, ACCELERATION MOBILITY, AND ACCELERATION RESPONSE AT 20 Hz FOR NODE 1

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE 1

MODAL ACCELERATION MATRIX A(NF,NM)

.2232E+00	.5435E+00	.1456E+00	.8816E-01	.5850E-05
.1913E+00	.1201E+00	-.1360E+00	-.1753E+00	-.3572E-04
.1549E+00	-.1620E+00	-.7962E-01	.8570E-01	.1340E-03

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE 1

ACCELERATION MOBILITY Y(NR,NF)

N	FREQ	YR	YI				
1	20.000	.5778E+00	.2394E+00	.1228E+01	-.8692E-01	.1027E+00	-.8742E-01

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE 1

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	.1950E+02	-.2439E+03	.2446E+03	-.8543E+02	.5046E-01	-.6311E+00	.6331E+00

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE 1

MODAL ACCELERATION MATRIX A(NF,NM)

.2232E+00	.5435E+00	.1456E+00	.8816E-01	.5850E-05
.1913E+00	.1201E+00	-.1360E+00	-.1753E+00	-.3572E-04
.1549E+00	-.1620E+00	-.7962E-01	.8570E-01	.1340E-03

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE 1

ACCELERATION MOBILITY Y(NR,NF)

N	FREQ	YR	YI				
1	20.000	.5778E+00	.2394E+00	.1228E+01	-.8692E-01	.1027E+00	-.8742E-01

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE 1

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	.3332E+03	-.1475E+03	.3644E+03	-.2388E+02	.8623E+00	-.3818E+00	.9431E+00

TABLE XI.- MODAL ACCELERATION, ACCELERATION MOBILITY, AND ACCELERATION RESPONSE AT 20 Hz FOR NODE 2

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE 2

MODAL ACCELERATION MATRIX A(NF,NM)

.1913E+00	.1201E+00	-.1360E+00	-.1753E+00	-.3572E-04
.1639E+00	.2654E-01	.1270E+00	.3484E+00	.2180E-03
.1328E+00	-.3579E-01	.7437E-01	-.1704E+00	-.8179E-03

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE 2

ACCELERATION MOBILITY Y(NR,NF)

N	FREQ	YR	YI				
1	20.000	.1228E+01	-.8692E-01	-.7060E+00	.1302E+00	-.5475E-01	.3997E-01

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE 2

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	.1655E+03	.6239E+02	.1769E+03	.2065E+02	.4284E+00	.1615E+00	.4579E+00

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE 2

MODAL ACCELERATION MATRIX A(NF,NM)

.1913E+00	.1201E+00	-.1360E+00	-.1753E+00	-.3572E-04
.1639E+00	.2654E-01	.1270E+00	.3484E+00	.2180E-03
.1328E+00	-.3579E-01	.7437E-01	-.1704E+00	-.8179E-03

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE 2

ACCELERATION MOBILITY Y(NR,NF)

N	FREQ	YR	YI				
1	20.000	.1228E+01	-.8692E-01	-.7060E+00	.1302E+00	-.5475E-01	.3997E-01

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE 2

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	-.1030E+03	.3067E+02	.1074E+03	.1634E+03	-.2665E+00	.7938E-01	.2780E+00

TABLE XII.- ACCELERATION RESPONSE AT 20 Hz FOR NODES 3, 4, AND 5

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE3

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	-.1591E+01	-.7660E+01	.7824E+01	-.1017E+03	-.4118E-02	-.1982E-01	.2025E-01

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE3

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	-.4523E+01	-.2692E+01	.5263E+01	-.1492E+03	-.1170E-01	-.6967E-02	.1362E-01

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE 4

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	-.3151E+02	.3574E+02	.4765E+02	.1314E+03	-.8155E-01	.9249E-01	.1233E+00

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE 4

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	.1611E+02	.4658E+01	.1677E+02	.1612E+02	.4170E-01	.1205E-01	.4341E-01

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 1*
RESPONSE LOCATION: RESPONSE AT NODE 5

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	-.2710E+02	.3239E+02	.4223E+02	.1299E+03	-.7013E-01	.8383E-01	.1093E+00

TEST CASE 1B FOR VIBRA ---CONSTRAINED SYSTEM---

APPLIED FORCE VECTOR: *FORCE VECTOR SET 2*
RESPONSE LOCATION: RESPONSE AT NODE 5

FORCING FREQUENCY (CYCLES/SEC)	REAL ACCEL (IN/SEC2)	IMAG ACCEL (IN/SEC2)	AMPLITUDE (IN/SEC2)	PHASE ANG (DEGREES)	REAL ACCEL (G)	IMAG ACCEL (G)	AMPLITUDE (G)
20.0000	.1470E+02	.4352E+01	.1533E+02	.1649E+02	.3805E-01	.1126E-01	.3968E-01

TABLE XIII.- INPUT DATA FILE 7 FOR CASE 2

```
OH58 TAILBOOM VIBRATION RESPONSE
6 12  1  0  0  1  1      75.00 300.00   1.00
NATURAL FREQUENCY (HZ)
.99269222E-03     .10557244E-02     .11938288E-02     .14050625E-02
.15454463E-02     .18585053E-02     .79266240E+02     .79623835E+02
.21336986E+03     .21621835E+03     .29678209E+03     .36830964E+03
GENERALIZED MASS
1.0
DAMPING
0  0  0  0  0  0  0.015  0.016  0.016  0.015  0.015  0.016
FORCE VECTOR 1.0 LBS DOWN AT NODE 193
(-1.0,0.0)
FORCE NODE 193    1 DIRECTION
 .30248530E+01   -.37951904E+01    .15550316E+01    .25379737E+01
 .94151486E-01   -.36754599E+01    .52681421E+01   -.26225012E+01
-.48201405E+01    .21011564E+01   -.14186734E+01   -.16998924E+00
RESPONSE NODE 109    1 DIRECTION
 .99372428E+00   -.26372378E+01   -.17557607E+01   -.12423869E+00
-.86123459E-01   -.98439780E+00   -.38250634E+01    .19295327E+01
-.10978691E+01    .49953624E+00    .50664644E+00    .24562881E+01
```

TABLE XIV.- CONTROL PARAMETER DESCRIPTION FOR CASE 2

```
                OH58 TAILBOOM VIBRATION RESPONSE

CONTROL PARAMETERS SET

NZ     =   6 *RIGID BODY MODES*
NM     =  12 *MODES TOTAL*
MNORM  =   1 *ORTHONORMAL MODES*
MDAMP  =   0 *STRUCTURAL DAMPING*
NZETA  =   0 *DAMPING VARIES*
NFS    =   1 *FORCE VECTOR SETS*
NF     =   1 *FORCE COORDINATES*
WSTRT  =  75.0 *STARTING FREQUENCY (HZ) *
WSTOP  = 300.0 *STOPPING FREQUENCY (HZ) *
DELW   =   1.000 *FREQUENCY STEP*

        BLANK COMMON STORAGE ZZZ REQUIRES   1443 LOCATIONS

        NOW COMPUTING FORCED RESPONSE
```

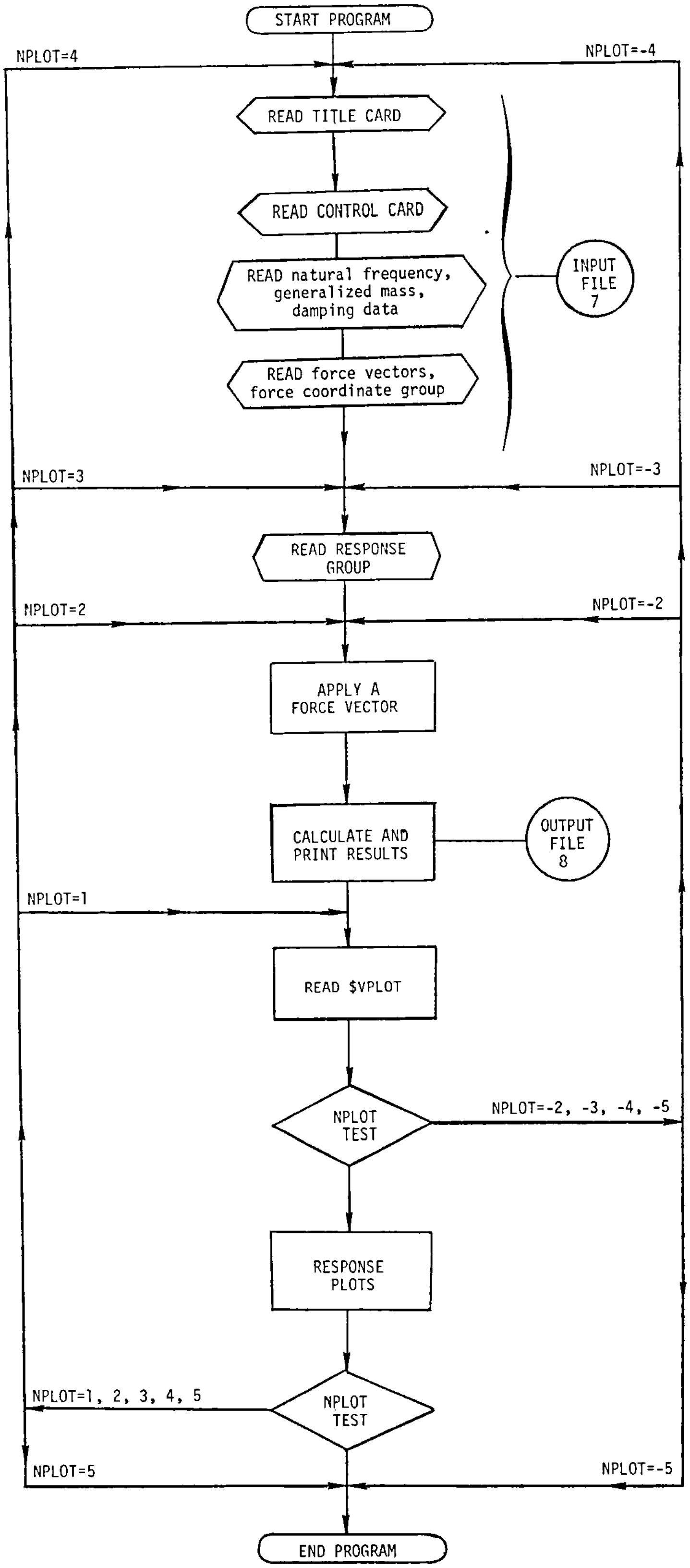
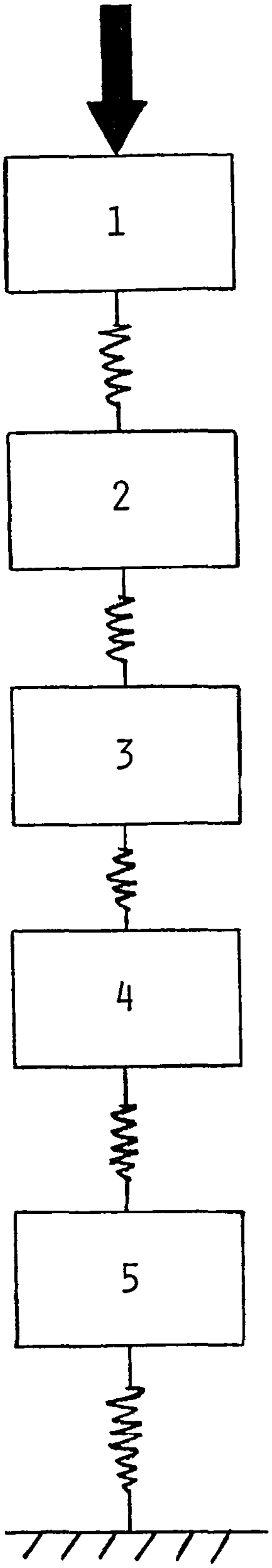
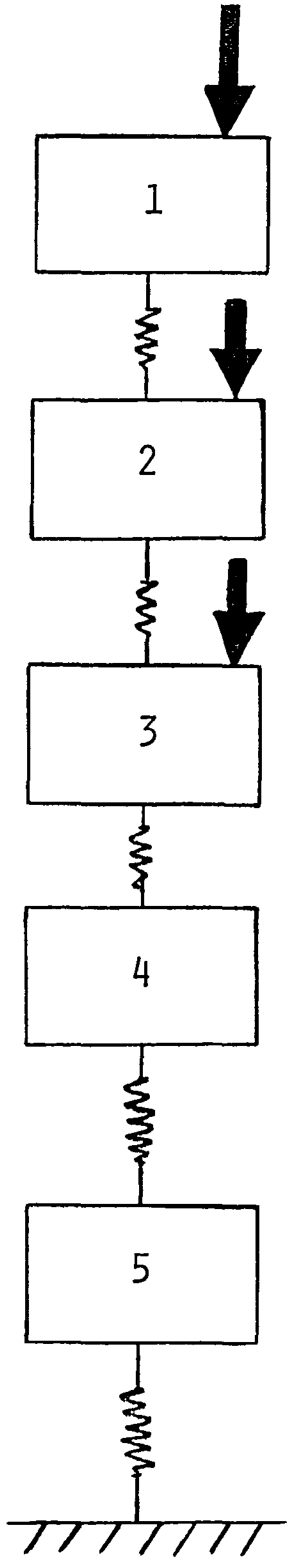


Figure 1.- Flow chart of VIBRA program.



(a) Case 1A.



(b) Case 1B.

Figure 2.- Constrained system for case 1.

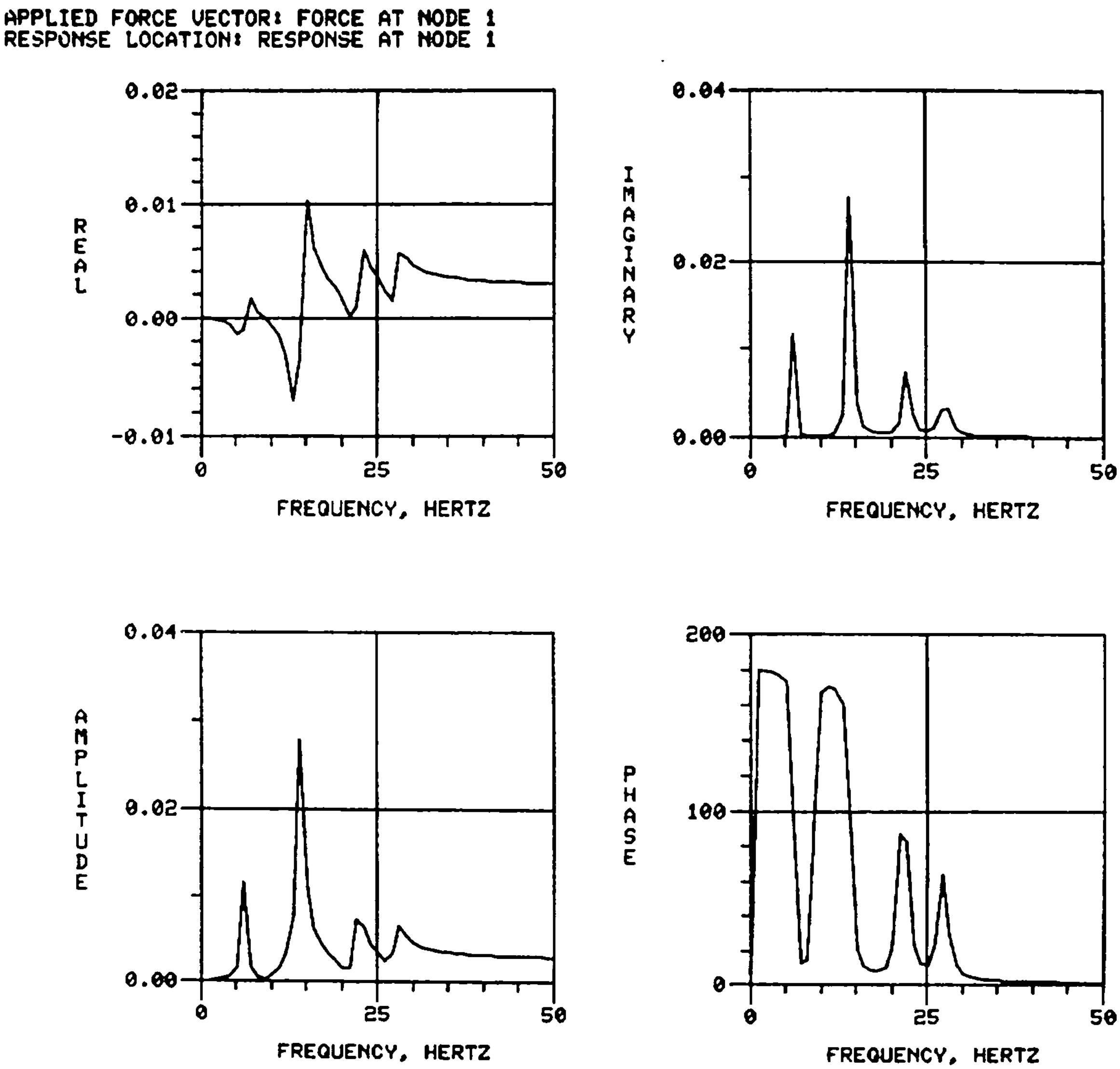


Figure 3.- Acceleration response components at node 1 for case 1A.

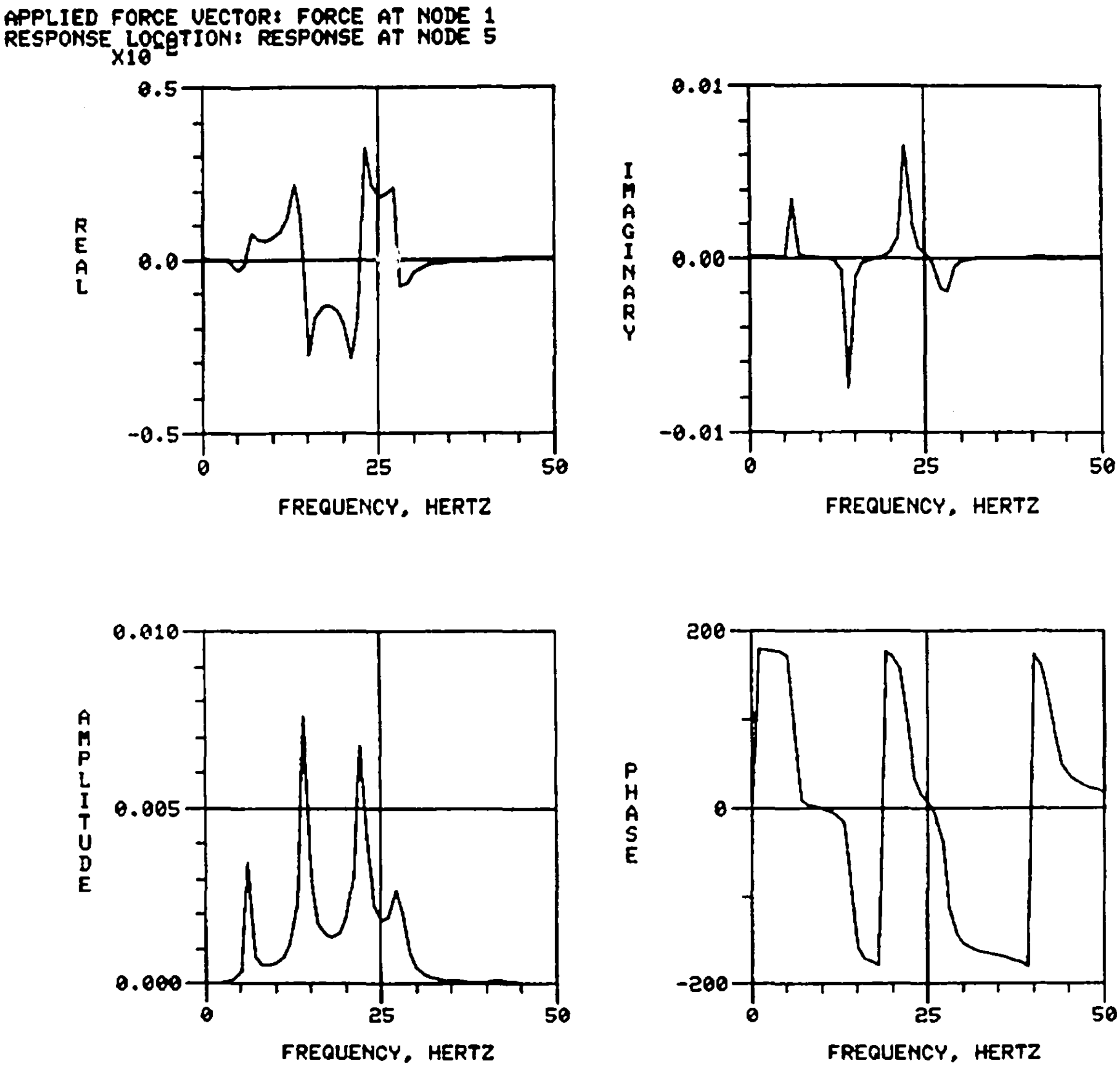


Figure 4.- Acceleration response components at node 5 for case 1A.

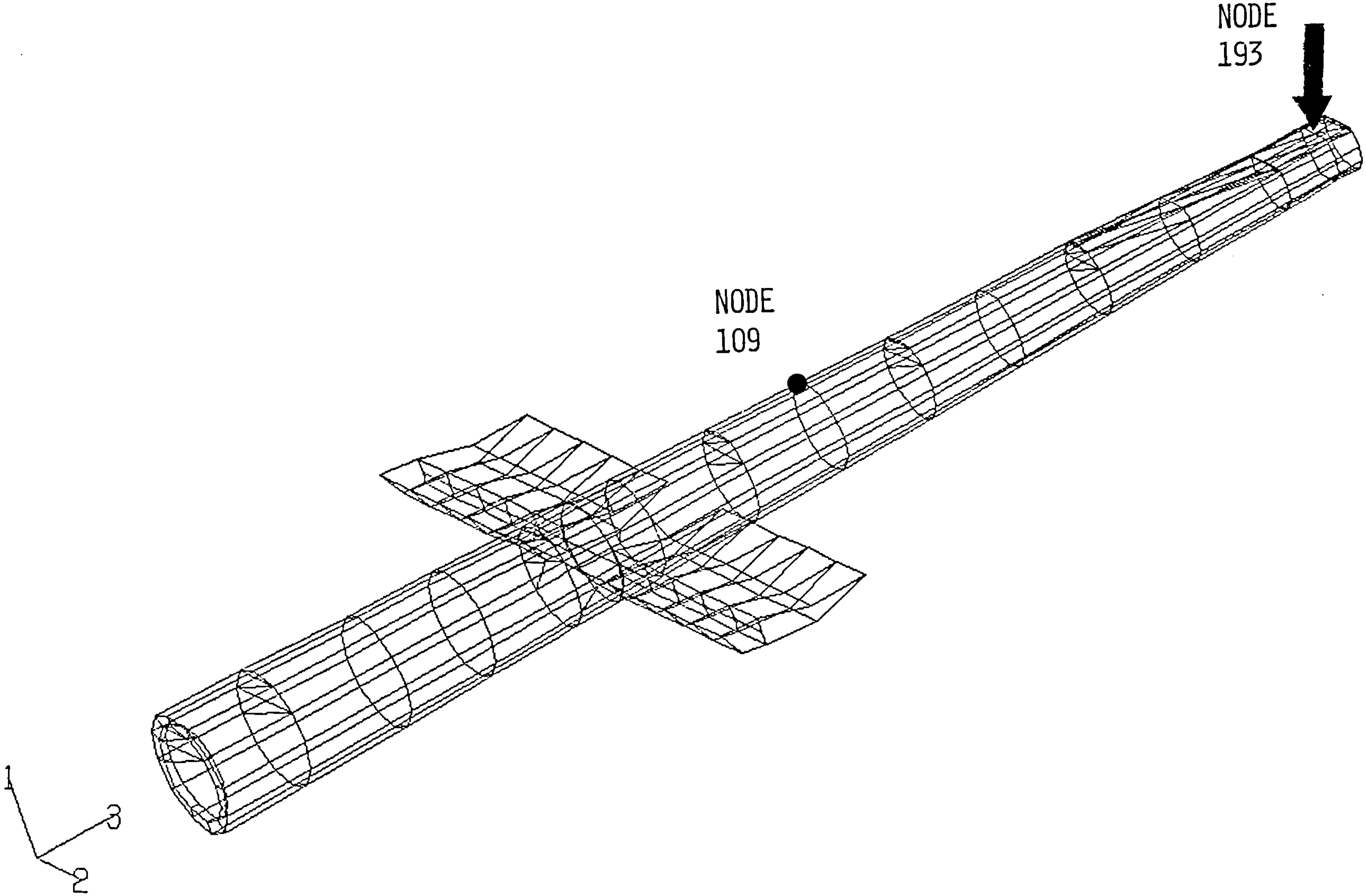


Figure 5.- Helicopter tail boom finite-element model for case 2.

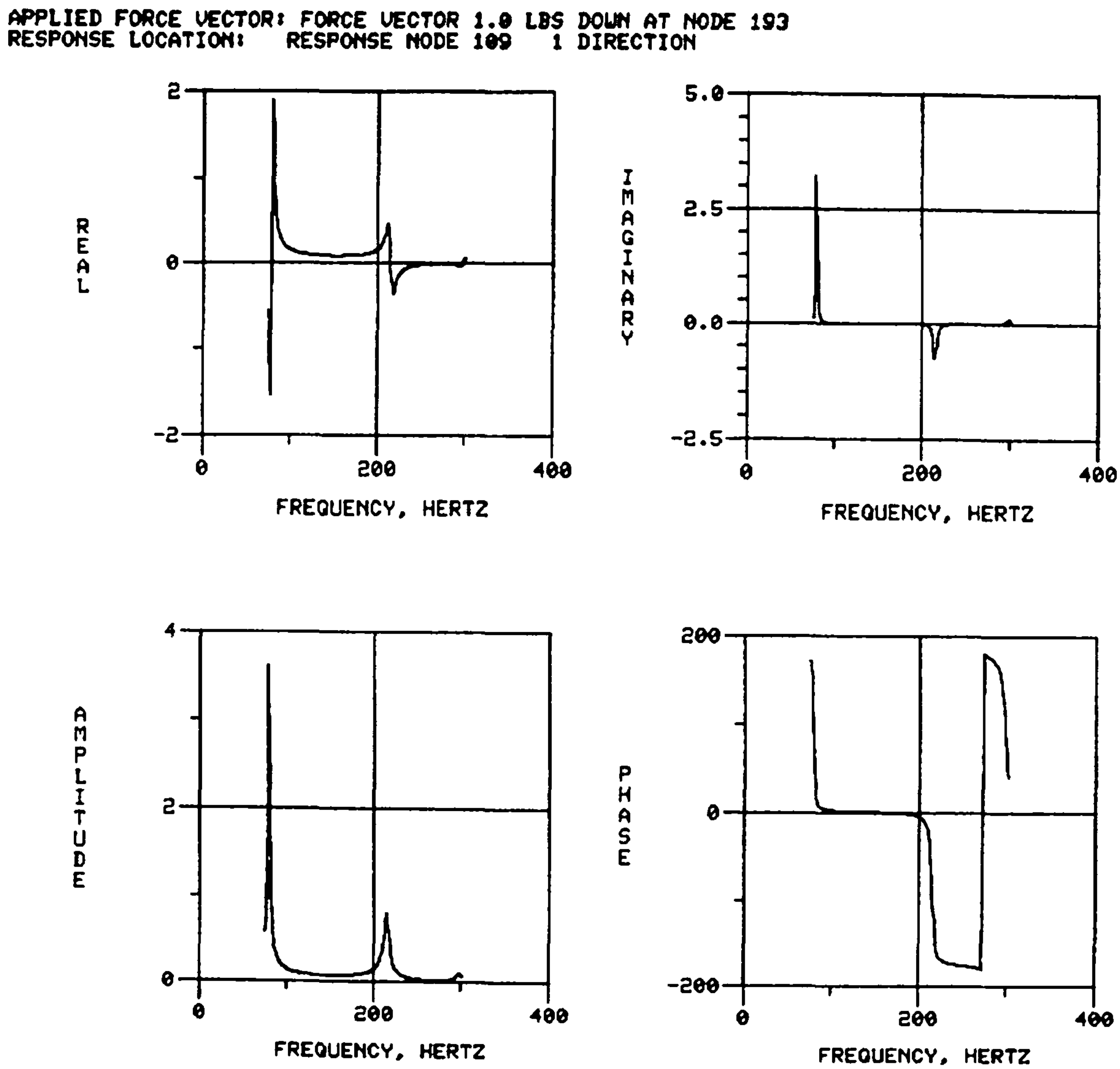


Figure 6.- Acceleration response components at node 109 for case 2.

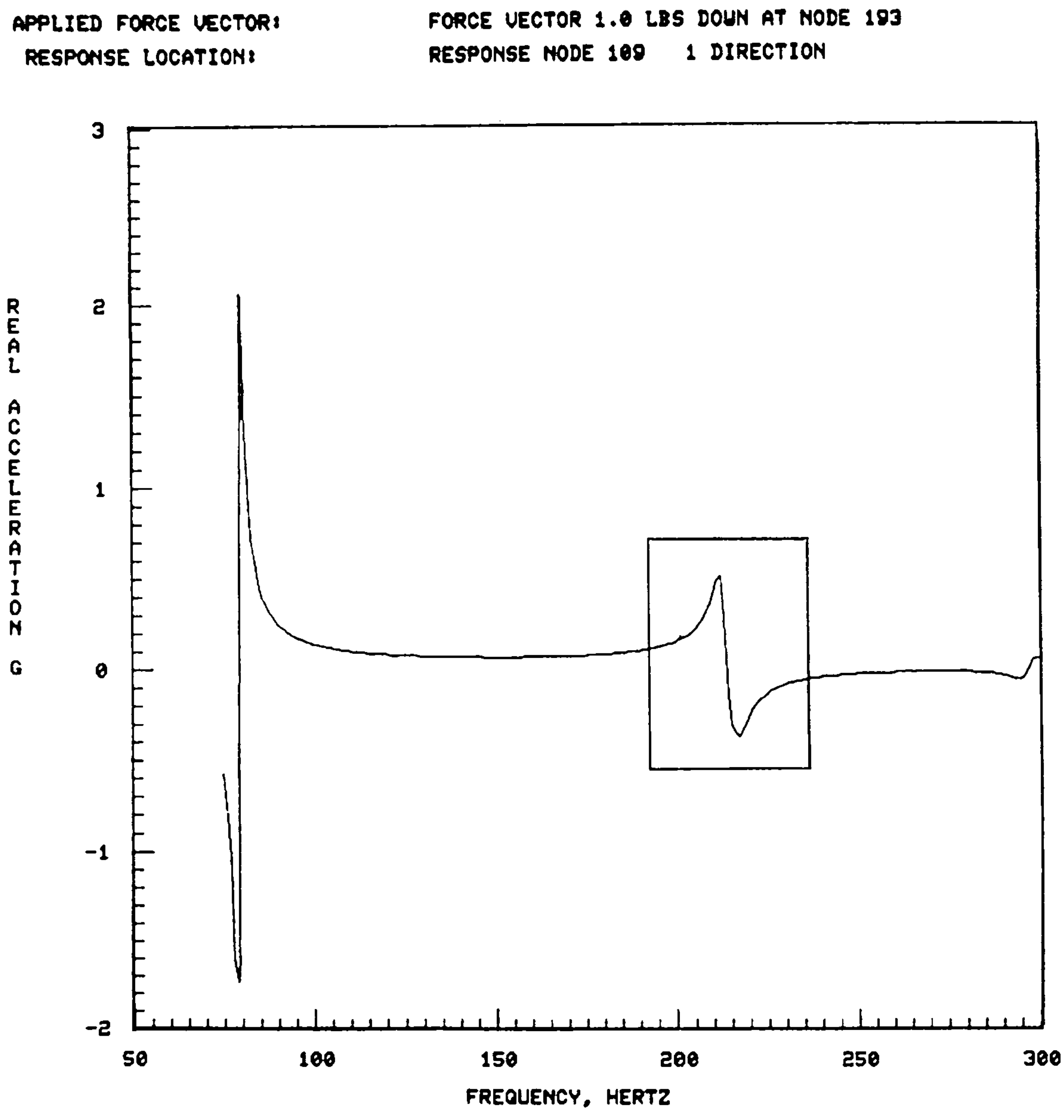


Figure 7.- Real acceleration response at node 109.

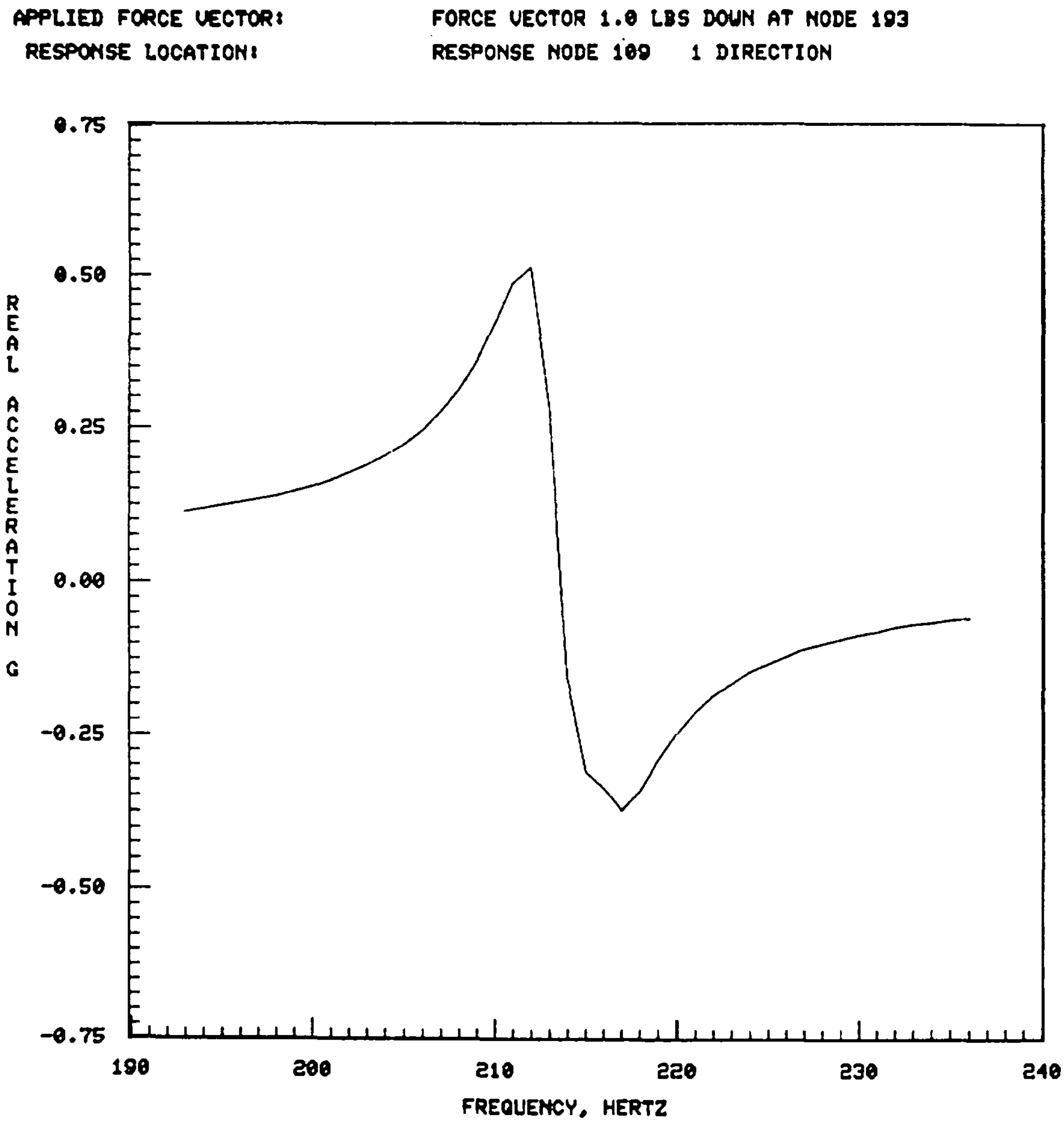


Figure 8.- Expanded plot of real acceleration component from figure 7.

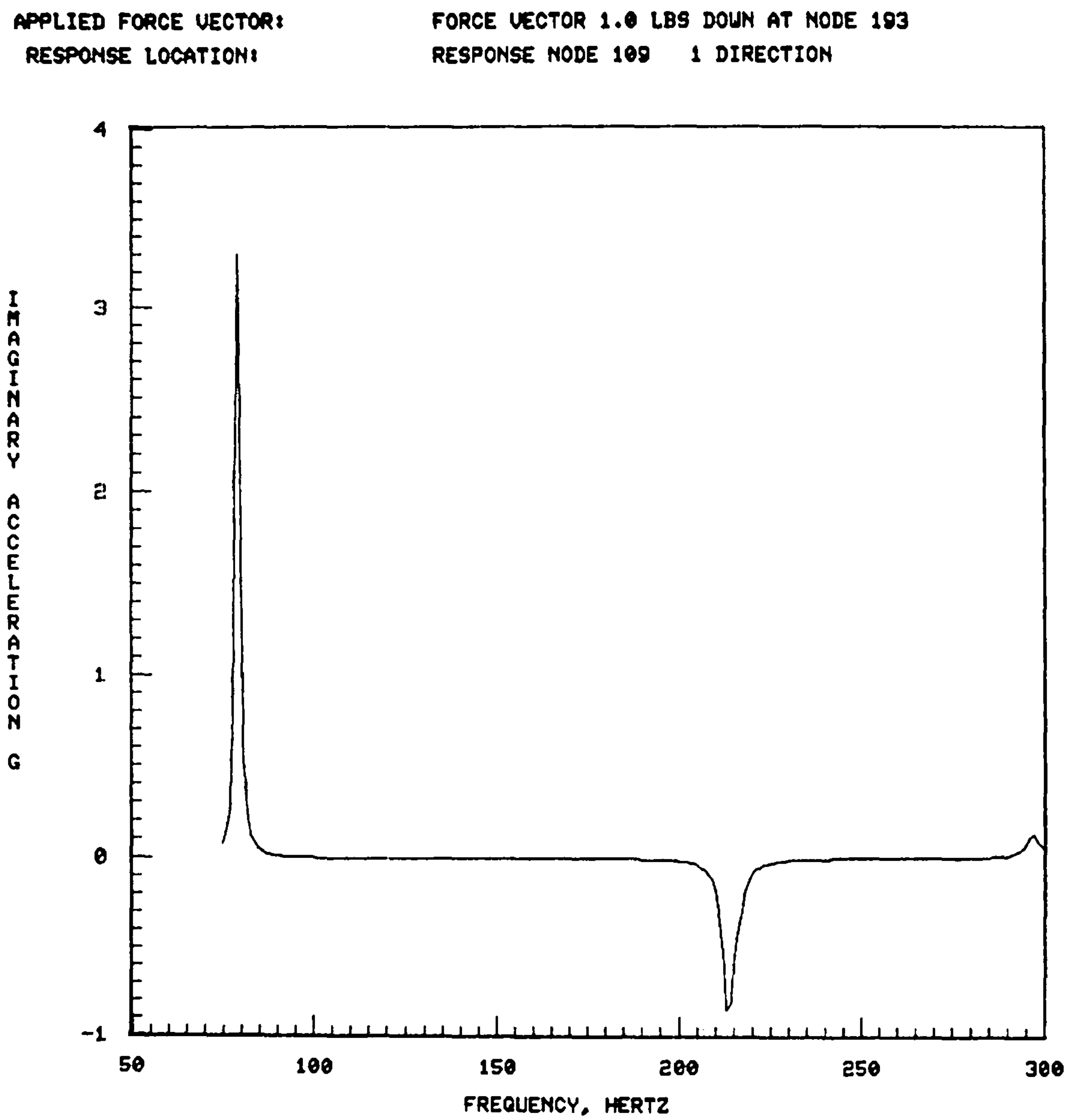


Figure 9.- Imaginary acceleration response at node 109.

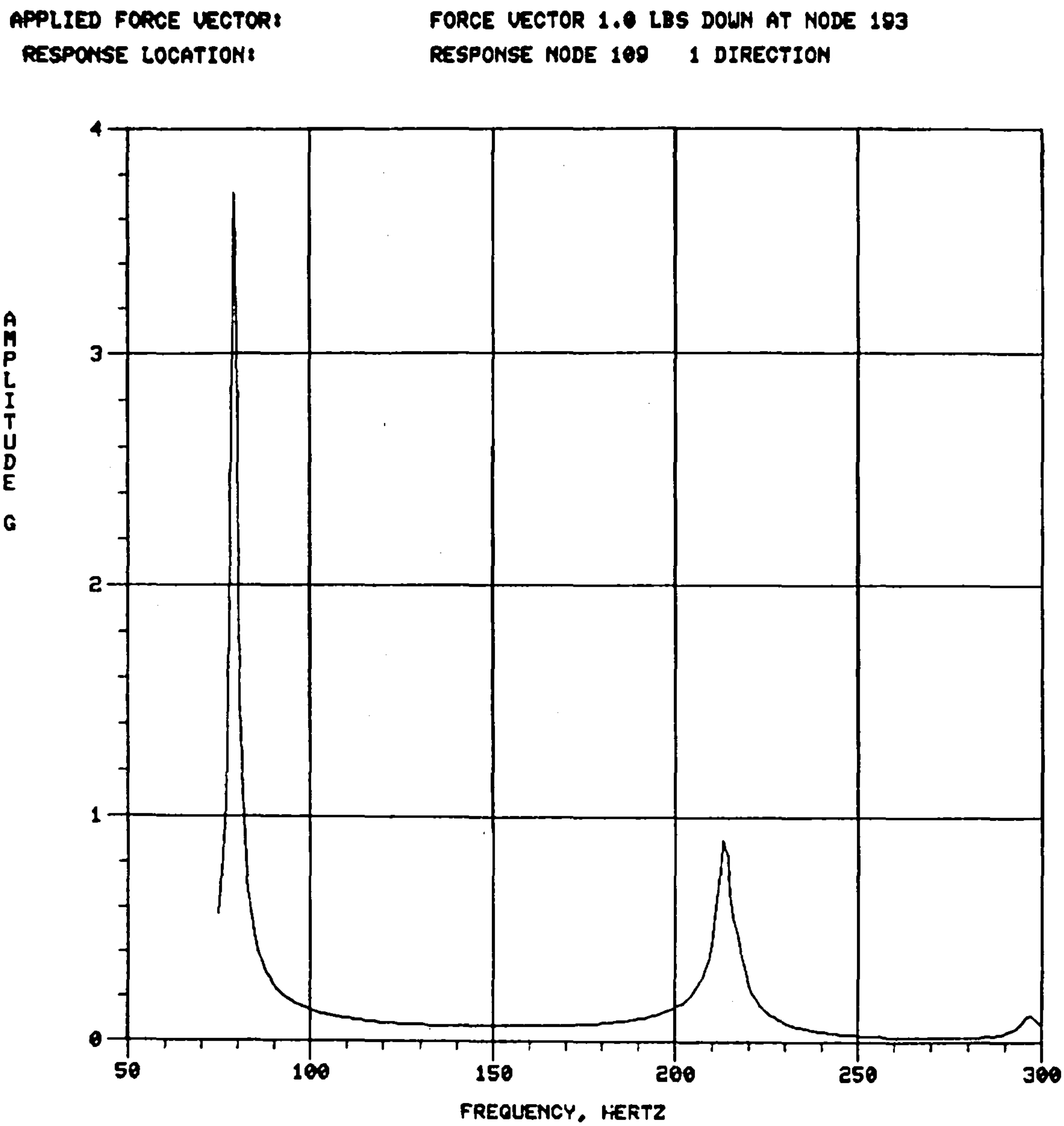


Figure 10.- Amplitude response at node 109.

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15. Supplementary Notes

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16. Abstract

An interactive steady-state frequency response computer program with graphics is documented. Single or multiple forces may be applied to the structure using a modal superposition approach to calculate responses. This method is applicable to linear, proportionally damped structures in which the damping may be viscous or structural. A general description of the theoretical approach and program organization is presented. Example problems, user instructions, and a sample interactive session are given to demonstrate the program's capability in solving a variety of problems.

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